Final Environmental Impact Statement

International Whaling Commission's Deletion of Native Exemption for the Subsistence Harvest of Bowhead Whales

October 1977

VOLUME II

Appendix A through I

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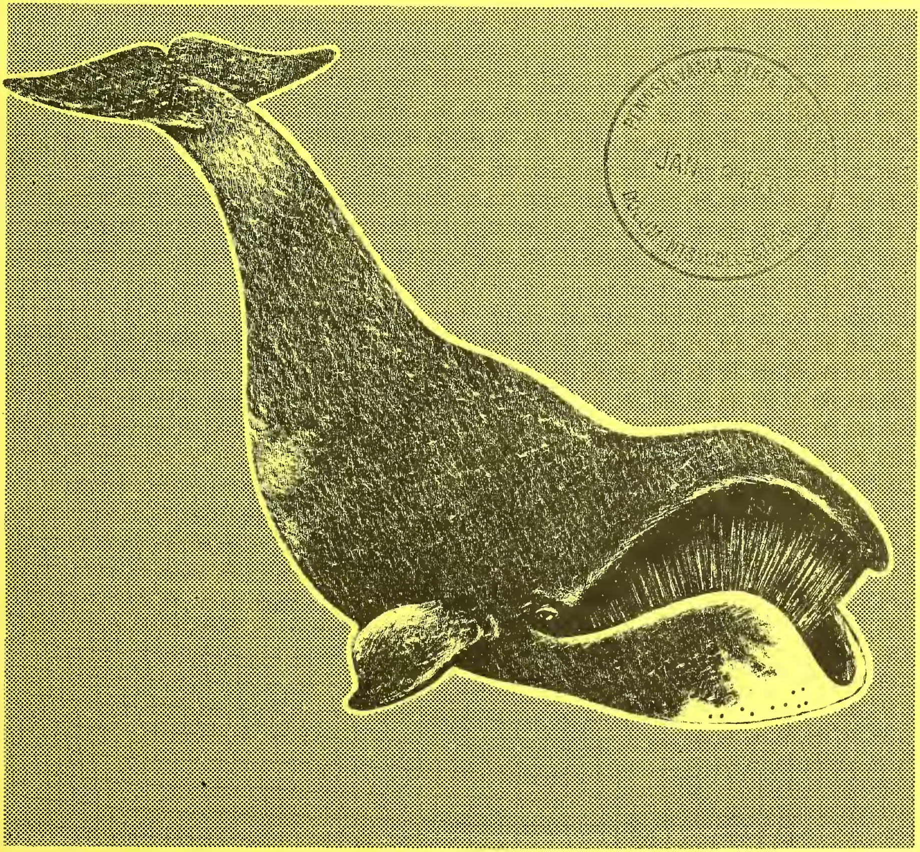

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APPENDIX B

UTILIZATION OF THE BOWHEAD WHALE

By

Geoffry M. Carroll

INTRODUCTION

The hunting of bowhead whales has been a very important part of Eskimo life since before 1800 B. C. (Oswalt, 1967, p. 43). Prior to the introduction of manufactured products to these people by commercial whalers and traders, the entire whale was used in one form or another to make tools, weapons, homes, and toys. With the passage of time, however, whale products have gradually been replaced by manufactured goods. This paper describes how the use of various whale parts has changed through the years.

Food

The most important parts of the whale have always been the meat and muktuk (layer of blubber with skin attached). Together, the meat and muktuk provide a large percentage of the food supply for the Eskimos of several whaling villages during a successful whaling year. The meat is a major source of protein and B vitamins, and the muktuk provides vitamins D and A and calories which are needed in large quantities to stay warm in the arctic (Davidson, 1972, p. 11-12). Both parts are eaten raw, frozen, boiled, or fried. The meat is sometimes made into "mekiqag" by placing it in a warm place and slow-cooking it in its own juices for a few weeks (Anonymous, 1967, p. 6, col. 2). This product is always served at whaling celebrations. Whale meat and muktuk are used in trading and are highly prized by Eskimos all over northern Alaska and Canada (Anonymous, 1967, p. 4, col. 3). An estimated 10,000 Eskimos and Indians outside the whaling communities supplement their diet with whale meat (Davidson, 1972, p. 13).

Other edible parts of the bowhead are the liver, brain, heart, and kidney. The small intestine is turned inside out, cleaned and eaten during the spring whaling celebration, the white gum material from around the base of the baleen is eaten raw, and clumps of blood from around the heart are sometimes consumed, but usually fed to the dogs (Robert Brower, pers. comm.).

Less desirable whale parts were once a very important source of dog food. Each animal consumed about 800 pounds of meat annually (Foote, 1965, p. 4), so a great deal of hunting effort was required to maintain a team of sled dogs. A successful whaling season solved the problem for most of the year, but because snow machines have largely replaced the dog teams, much less meat and blubber are now used for animal food.

Heat and Light

Blubber has been traditionally rendered into oil through autolysis, by cutting it into small pieces, scoring it with a knife, and putting it into barrels (Davidson, 1972, p. 13). The oil was used mostly as a fuel in soapstone and sandstone lamps with sphagnum moss wicks to heat and light igloos (Murdoch, 1885, p. 62). It was also used as a dip for foods (Nelson, 1889, p. 73), cooking oil (Anonymous, 1968, p. 5, col. 1) and, when mixed with red ochre, as a dye (Oswalt, 1967, p. 173). Because of its value as a fuel, whale and seal oil were also used by coastal Eskimos to barter with inland people for caribou and wolverine skins (Oswalt, 1967, p. 132).

Commercial Products

During the commercial whaling period, blubber was rendered into oil by heating and sold for use in lamps, for tanning leather and preparing wool cloth, and for manufacturing soap, candles, paints, varnishes, and lubrication oils (VanStone, 1958, p. 1; 1962, p. 21). One large bowhead yields up to 275 barrels of oil (Scammon, 1874).

Baleen has lost its importance as a raw material for the making of practical items (it is used in artwork), but its qualities of flexibility and formability once allowed it to be used in an almost endless variety of ways.

During the period of commercial whaling, the taking of baleen to be processed into corset stays, buttons, parasols, umbrellas, women's hats, upholstery, frameworks for trunks and suitcases, fishing rods, buggy whips, and carriage wheels and springs was a profitable business (VanStone, 1958, p. 1). Each whale contained several hundred pounds of baleen which sold for $2 per pound in 1880 and $4.90 per pound in 1905, making a large whale worth up to $10,000. Values such as these led to an increase in the number of whalers and a corresponding reduction in the number of whales. In 1885, 441,400 pounds of baleen from the

Arctic were marketed and in 1887 and 1889, 561,694 and 219,400 pounds, respectively, were sold. By 1905, only 38,200 pounds were taken despite a price of nearly $5 per pound (VanStone, 1962, p. 24). Baleen was replaced by other products shortly thereafter and the market eliminated.

Eskimo Implements

The Eskimos cut baleen into strips, then braided and tied them into lines (Murdoch, 1885, p. 76) which remained strong through prolonged use in saltwater (Davidson, 1972, p. 15). Because of this strength, baleen was a good material for fishlines (Oswalt, 1967, p. 124) and boat and sled lashings (Ray, 1885, p. 27). Baleen strips were also woven around the prongs of a caribou antler to make a scoop for removing ice from ice fishing holes (Murdoch, 1885, p. 79). Baleen lines were used to make gill nets for catching whitefish (Oswalt, 1967, p. 27), to tie sinkers onto the nets (NARL Museum Display), to hold the mouth of dip nets open (Nelson, 1969, p. 148), and as a mesh and support for crab traps (Oswalt, 1967, p. 140).

Baleen was also used to make containers. Cups, dishes, and dippers were made by bending baleen around a wooden base, and buckets were made by sewing overlapped pieces of baleen together to make the sides (Murdoch, 1885, p. 62).

Walking sticks had baskets like those on ski poles which were made of strips of baleen wrapped so as to form a circle (NARL Museum Display). Sleds, made by sewing several pieces of baleen together side by side, were easily carried while hunting and were used to drag seals or materials back to the village (Bandi, 1969, p. 11). Sleds of this type are still used on St. Lawrence Island.

Baleen had many practical uses such as knife blades for cutting blubber (Murdoch, 1885, p. 67), rivets in many implements such as shovels, knives, picks, and harpoons (Murdoch, 1885, p. 67), and as insoles in shoes (Oswalt, 1967, p. 140). Strips of baleen were also used to hold lids on boxes (Murdoch, 1885, p. 67), and windows were made of the transluscent membrane of seal entrail stretched by a piece of baleen (Murdoch, 1885, p. 67).

Whalebone was also used extensively because it was strong and easily workable (Oswalt, 1967, p. 152). The ribs of young whales, particularly ingutuks, made good, versatile sled runners because of their hardness and lack of pitting peculiar to the ribs of older whales.

Sled runners made of whale ribs slid easily over tundra, ice, or snow (Sonnenfeld, 1956, p. 489). Jawbones have been used as sled runners (Ray, 1885, p. 27) and also as umiak keels to prevent wear while these boats are being dragged over the ice during spring whaling (Sonnenfeld, 1956, p. 489). The jaw bones and ribs were used as frames in building sod igloos (Sonnenfeld, 1956, p. 489).

Whalebones were used in making the heads of mauls, handles for knives, the foreshafts of darts thrown with a darting board, the handles and blades of an adze, the blade of flint flakers, shafts of flensing knives, sinew shuttles, weaving tools, needle cases, pipe bowls, water ladles, braces to protect the arm from the snap of a bow string, and net weights.

Hand clubs were made from a short blunt piece of bone, and a piece of whale rib lashed to a shaft made a mattock. The handle and blade of an adze could be made from whalebone, and the scapula or shoulder blade was used to make snow shovels (Murdoch, 1885, p. 79). Harpoon heads were sometimes made from whalebones (Larsen and Rainey, 1940, p. 69). In Point Hope, jawbones were used to support burial scaffolds (Davidson, 1972, p. 16), and to form a palisade around the cemetery.

Animal Traps and Spears

The flexibility of baleen was a quality useful for taking wolves and bears. Spring-baits were made by sharpening both ends of a 6-inch piece of baleen, wetting it, then tying it folded into lengths of 1-1/2 to 2 inches until it dried. The baleen was then placed inside a piece of fish skin or blubber and after an animal had injested it the moisture and body heat caused the folded baleen to straighten and pierce the stomach wall (Murdoch, 1885, p. 77).

Nooses made of baleen were used to trap ground squirrels as they passed through their tunnels (Nelson, 1889, p. 118) and also birds when they returned to their nests (Murdoch, 1885, p. 77).

Fox traps were made by placing pieces of baleen over holes in the ice or snow and covering them with snow. Bait was placed on one side and a drift fence constructed so that the fox had to pass over the trap. In doing so, the fox fell through and was impaled on caribou antlers that had been placed in the bottom of the hole. In another version of this trap, strips of baleen were placed on the ice with their ends radiating inward to cover a large hole. When the fox fell through, the baleen snapped back into position and the trap was automatically readied for another animal (Nelson, 1969, p. 182).

Baleen prongs with spurs on them were attached to the tips of fish spears so that when the sharp middle prong entered the fish, the flexible baleen pieces slid by, and the spurs became extended and kept the fish from sliding off (Murdoch, 1885, p. 67). Bow shafts were sometimes made with baleen (Bandi, 1969, p. 11).

Toys

Many toys were made from baleen because of its flexibility. A marionette made from a fox skin supported by a piece of baleen down the back was worked with strings so that it would dart its head at a toy leming (Murdoch, 1885, p. 67). Baleen was also used to make a doll's arms so that when pushed, this toy would beat a drum or paddle a canoe (Murdoch, 1885, p. 67). In addition, baleen was used to make a device used by boys to snap pebbles at targets and to sew liver membrane onto drums (Murdoch, 1885, p. 67).

Arts and Crafts

Baleen is now used almost exclusively in arts and crafts. Bracelets, baskets, miniature boots, sleds, and baleen etchings are most frequently made. Baleen is also used as inlay material in ivory, whalebone, and driftwood art objects (Davidson, 1972, p. 16). The price of these items is rising rapidly. In 1974, a 5-inch high baleen basket with an ivory carving attached sold for $80 to $120 and, in 1975, $150 to $200.

Whalebone is now used in making such art objects as bears, birds, whales, and seals, and artifacts are often reproduced from this material.

Summary

The bowhead whales' value as food has not changed, even though a wide variety of domestic meat is now available to the Eskimo. As manufactured goods, more convenient to use, have become increasingly abundant in the Arctic, however, traditional uses of the bowhead whale have disappeared. Bone has been replaced by metals and baleen by rope and plastics. Driftwood, petroleum products, electricity, and (at Barrow) natural gas have replaced whale oil as heating fuels. Blubber is occasionally burned in camp stoves and ceremonial fires (Ed Wightman, pers. comm.), and, is still used in whaling tent fires at Point Hope. In 1950, the people of Point Hope sent 40 drums of whale oil to Seattle in an attempt to develop a market for the product, but to no avail (VanStone, 1962, p. 144).

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Appendix C is information on bowhead whales taken from the Report of the Scientific Committee (IWC/29/4) of the 29th Annual Meeting of the International Whaling Commission.

Document citations in the text are further explained:

SC/29/Doc. 6

Beddington, J.R. On the risks associated with different harvesting strategies.

*SC/29/Doc. 10

Braham, H.W. and Krogman, B.D., Population Biology of the Bowhead (Balaena mysticetus) and Beluga (Delphinapterus leucas) Whale in the Bering, Chukchi and Beaufor Seas.

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Marquette, Willman M. The 1976 Catch of Bowhead Whales (Balaena mysticetus) by Alaskan Eskimos, with a reivew of the fishery, 1973-1976, and a biological summary of the species.
Note, this is included as Appendix E of this DEIS.

*SC/29/Doc. 33

Mitchell, E. Initial population size of Bowhead Whale (Balaena mysticetus) stocks: Cumulative catch estimates.

*Copies of these documents are available upon request from the following agencies.

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NMFS - Juneau, FAK
P.O. Box 1668
Juneau, Alaska 99802
Seattle operator: 8-399-0150
Ask for: 907-586-7221

NMFS - Washington, D.C.
Page Bldg. #2, F33
Washington, D.C. 20235
phone: 202-634-7461

FWS - Fairbanks:
1300 College Road
Fairbanks, Alaska 99701
phone: 907-452-1531

N 1

13. PROTECTION STOCKS, REVIEW OF STATUS

The Committee agreed that at the next meeting it would undertake stock assessments on Protection Stocks approaching the Sustained Management Stock category. It reviewed available evidence on all stocks as follows:

13.1. Bowhead whales

At its 28th meeting the Committee indicated an urgent need, because of its concern about the safety of this species, to limit the increasing effort in the Alaskan bowhead fishery and to gather information to permit an evaluation of stock conditions. The Committee reviewed the new evidence available, noting that marking studies had not been undertaken and reiterating the urgent need for them. It explained that its intention in this regard was to suggest serial numbering of shoulder gun bombs to provide some indication of the 'struck and lost' survival rate and possible reference to faulty batches of bombs.

The Committee considered the species on the basis of five stocks as follows:

SPITZBERGEN STOCK

The Committee had a review (SC/29/Doc.33) of the history of exploitation indicating an initial stock in 1679 of approximately 25,000 bowheads. The absence of sightings from other whaling vessels indicates that the stock is now at a very low level.

DAVIS STRAIT STOCK

SC/29/Doc.33 indicates an initial stock of approximately 6,000, and a present stock of approximately 10% initial.

HUDSON BAY STOCK

This stock was proposed (SC/29/Doc.33) to be newly recognised. Initial size may have been approximately 700; present size is approximately 15% of initial.

BERING SEA STOCK

The Committee had available reports of studies of bowhead whales in Alaska to 1976 (SC/29/Docs 10 and 30), and an historical summary and evaluation of the stock (SC/29/Doc.33). A previous estimate of stock size of 4,000-5,000 by Rice (1974 in Schevill, The Whale Problem, Harvard Univ. Press) was derived from data on whaling in the period 1868-1884. SC/29/Doc.33 identified an earlier peak catch period, provided vessel extrapolations, summarized data on loss rates, and concluded that initial stock size in 1850 was a minimum of 11,700 (10 year peak catch plus adjustment for losses), and probably approximately 18,000 (adjustment for residual stock). The present size may be 1,000 bowheads, approximately 6% (to 10%) of initial size. Available evidence shows no increase in loss rates from 1920-1975 (SC/29/Doc.33), but recent catches are increasing.

SC/29/Docs 10 and 30 indicated that 1976 was a record season, recent catches representing a threefold increase in the last seven years. The Table below summarises data for the last four years from SC/29/Doc.30 and includes preliminary data for the spring 1977 season presented by Tillman.

Number of bowheads taken, known killed but lost, and known struck but lost, in Alaskan eskimo fishery 1973-77

	Number Landed	Number killed but lost	Number struck and lost
1973	37	0	10
1974	20	3	28
1975	15	2	26
1976	48	8	35
1977*	26	2	77

* Incomplete; data for 1977 autumn season to be added.

The increase in catch was associated with caribou take restrictions and an increased availability of cash for whaling activities

arising from petroleum exploration employment and settlement of compensation claims relating to land rights.

Losses of struck or killed animals increased in 1976 associated with a progressive change from using the darting gun to use of the shoulder gun. Bombs from the latter frequently fail to detonate and do not incorporate a fixing line as a standby. Bertrand advised that proposed USA declaration as a depleted species would allow USA quota establishment and whaling control, but not before 1978 and only if complex aboriginal rights issues can be overcome. The Committee felt that use of the shoulder gun should be prohibited in any event to stop the unnecessary losses.

Ivashin explained that USSR had overcome high loss rates in their aboriginal fishery by providing a special catcher 10 years ago which replaced aboriginal methods of hunting; this applied mainly in the gray whale fisheries. In recent years only one or two bowheads had been taken in occasional seasons and these by traditional methods.

OKHOTSK STOCK

Few useful statistics were available for this stock. SC/29/Doc.33 provided a vessel extrapolation, and an estimated initial stock size of approximately 6,500 bowheads. The present population size is unknown exactly, but few survive.

The Committee expressed its appreciation of the very useful compilation of information presented in SC/29/Doc.33.

Taking into account its apprehension last year about the safety of the species, the Committee viewed with real concern the continued increase reported above and the continued high loss

rate. It noted that at a time when there has been considerable pressure for a moratorium on commercial whaling on stocks in a sound condition, the species most endangered is one which has been subject to such a moratorium for about 40 years. The stock assessment details above suggest that current population size for the Bering Sea stock is from 6-10% of estimated initial population size and for the species as a whole is between 2-3% of initial population size, clearly placing the stock in the Protection Stock category. Despite this, the kill rate in the Bering Sea stock continues at about at least 5% of current population size and shows an increasing trend. In contrast, the Scientific Committee has only endorsed an exploitation rate as high as 5% for those stocks in the Initial Management Stock category.

Rev. 1
N 4

The Committee noted with concern that 3 bowheads have been recorded as killed from the Hudson Bay population during the past 6 years and that further unsuccessful hunts have been recorded during 1975 and 1976 (SC/28/Prog. Rep.3, SC/29/Prog. Rep.2).

The Committee believes that on biological grounds exploitation of this species should cease and recommends to the Commission that the words "or right" in paragraph 7 of the Schedule be deleted. In making this recommendation, the Committee has taken into account the potential pollution hazard associated with petroleum development in the North American Arctic and its possible critical consequences for stocks at low levels of abundance. A particularly serious consequence of this high rate of exploitation of a small stock is the attendant instability of the system in the face of environmental perturbations. Such problems, examined in detail in SC/29/Doc.6, are exacerbated when a stock is at a low level relative to its initial size.

The Committee decided to review in more detail at its next meeting the question of aboriginal whaling on all species listed in the Schedule, giving particular attention to the possibility of suggesting safe quota limits within which national control could operate.

In response to a request by the Commissioner for from the U.S/A., the Committee provided further comment in Annex L.

Suggested additions to S.C. N2-N4 (Bowheads)

N2

Line 13 - (change sentence)

The best available scientific evidence indicates that the stock size may be as high as 2000 and low as 600, 6 to 10 per cent of an estimated initial stock.

N3 - End of 1st full paragraph strike "in any event to stop the unnecessary losses".

N4 - 2nd line, 2nd full paragraph replace should with must.

End of same paragraph

The Committee agrees that the bowhead whale stocks are in such a state.

The Committee believes that any taking of Bowhead Whales could adversely affect the stock and contribute to preventing its eventual recovery, if in fact such recovery is still possible. No bowhead whale stocks have shown any discernable increase since protection began 40 years ago.

Proposed addition to the report on the Bowhead Whales as requested by U.S. Commissioner *

ANNEX L

The reduction of the bowhead whale to a small fraction of its initial population level poses two inter-related questions about the chances of survival of the species. In the absence of exploitation, environmental fluctuations will be expected over time to reduce the population below a critical level where extinction is likely. The smaller the population the higher the risk and the shorter the time to extinction. However, where the population is subject to exploitation this problem is considerably exacerbated; if a quota is set and at any time some natural disaster reduces the population to any degree, continued application of the quota will result in severe depletion and a correspondingly shorter time to extinction. This risk is only slightly reduced if an effort regulation is used. Accordingly there is a clear scientific case to be made for a moratorium on this species in the hope that it will recover to a somewhat safer level.

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* This report on the bowhead whale, contained in the Appendix, was provided by the Scientific Committee of the IWC in response to a request by the U.S. Commissioner for further information as to why some level of subsistence taking above zero harvest could not be permitted.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

NOAA, NATIONAL MARINE FISHERIES SERVICE
MARINE MAMMAL DIVISION, NWAFC
7600 SANDPOINT WAY N.E.
SEATTLE, WA 98115

8 August, 1977

To: Robert W. Schoning, Director
National Marine Fisheries Service

Michael F. Tillman

From: Dr. Michael F. Tillman, Leader
Cetaceans Task Unit, F113

Subject: Analysis of IWC Scientific Deliberations Concerning Bowhead Whales

Four sources of new data were presented to the Scientific Committee (SC) for its deliberations on the bowhead whale situation. SC/29/Document 10, by Braham and Krogman, provided estimates of the number of bowhead whales passing by Pt. Barrow during the 1976 NMFS survey. SC/29/Document 30, by Marquette, provided catch statistics collected by NMFS for the 1976 season and compared these to past seasons' data. SC/29/Document 33, by Mitchell, provided an estimate of the abundance of bowhead whales at the start of exploitation (initial level). Finally, Tillman provided an oral report on the catch statistics obtained by NMFS from the spring, 1977 hunt.

It should be noted that Documents 10 and 30 were the primary responses of NMFS to the SC requests that an assessment of current population status be made and that collection and compilation of better biological data for captured whales be undertaken. An analysis of all of these new sources follows.

Initial Stock Size

Document 33, by Mitchell, provided a new estimate of initial stock size which was based upon catch rate data from Townsend (1935). Mitchell first provided an analysis indicating that the peak years of exploitation for the Bering - Chukchi - Beaufort Seas stock was during 1851-1860. Document 10, by Braham and Krogman, independently concurred with this finding. Hence, Rice's (1974) identification of 1868-1886 as the peak period is in doubt and his estimate of 4,000 - 5,000 is probably too low.

The average catch rate of 8.1 bowhead whales per ship per year obtained from Townsend (1935) assumes that his data represent an unbiased sample of American whaling voyages during 1851-1870. Only a full study of logbooks could test this assumption, and until such a study is completed Mitchell's assumption does not seem unreasonable. This catch rate was then multiplied by the annual effort (number of ships) participating each year in the bowhead fishery. Effort was calculated as 57% of the total number of American and foreign vessels whaling in the north Pacific. Mitchell presents reasonable arguments for regarding 57% as a minimum.

Summing results over the period 1851-60 is a reasonable cumulative catch procedure and gave a value of 8,852 whales taken over 10 years. A minimum estimate of abundance would then be obtained if some correction for losses were applied. Mitchell's use of 24% of the number killed and captured as being the number lost seems somewhat low but his assumption that all of these die would appear to compensate as he suggested. (That all whales struck and lost die appears valid since only loss data for whales struck with darting guns were used in determining the loss rate). His corrected cumulative catch estimate of 11,647 (8,852/.76) consequently seemed reasonable to the SC.

However, several members of the SC disagreed with Mitchell's method of adding in a factor for "residual stock". The procedure he used is not clear. If his value of 18,000 comes from adding in the estimated cumulative catches adjusted for losses in the succeeding two decades (1871-1890) as given in his Table 12, then he has surely added in some new animals produced after exploitation started. A better correction would have been to adjust his cumulative catch estimate for natural mortality (assuming a 5% rate, 11,647/.95 = 12,260).

Current Stock Size

Document 10, by Braham and Krogman, presented the first systematic sightings data ever produced for bowhead whales migrating past Pt. Barrow. An ice camp maintained 24-hour surveillance during 25 April to 2 June, 1976 and counted 357 animals (includes 98 whales sighted by nearby Eskimos). The mean number of whales seen per hour by observers was 0.61 or 0.85, if Eskimo sightings are included. For the 936 hours of observation, an estimated 571-796 bowhead whales passed by the ice camp during the survey period. Moreover aerial surveys flown offshore, west of Barrow, did not reveal any use of offshore leads.

The SC therefore believed that the component of the bowhead stock affectedby Eskimo hunting was at least 600-800 animals. Since the survey period did not cover the full migratory period, March through July according to Document 10, the SC allowed that a few hundreds must also pass by before and after the survey period or peak. Certainly, no more than double the survey estimates or 1200-1600 were believed available. The SC decided that the "best" estimate was somewhere between these two extremes and settled upon 1000 animals as most likely. This appears to be the best use of the available data. (Preliminary examination of the 1977 spring counts by ice station crews indicates that similar results would be obtained with 740-870 animals estimated for the survey period, 23 April - 3 June).

It should be noted that the validity of the above estimates far exceeds that of previous estimates, which should therefore be discounted. The estimates of Rice (1000 animals, 1964 ms), Harry (1000-3000 animals, 1973 ms), and Fay (1000 animals, 1975) are simply guesses or have no factual basis. In light of the 1976-1977 ice station counts, Rice's (1974) estimate of 400 (based upon average removals of 10 killed plus 10 lost which die and assuming a stable removal rate of 5%) seems too low. In Tillman's opinion, Durham's (1973 ms) estimate of 2500 is based upon incorrect interpretation of data (28 rather than 50 whales per day passed by Pt. Barrow during a run). Given 28 whales per day, 6 days per run, and 4 runs per season, about 670 whales would be estimated, which agrees with the ice station data.

Recent Catch Statistics

Document 30 and Tillman's oral report gave data on the numbers of whales killed and recovered, known killed but lost, and known struck but lost. The number killed and recovered each season are based upon actual counts. However, the numbers killed but lost and struck but lost are based upon interviews with Eskimo hunters when they return to ice camps. Consequently we believe that these data are underreported and that the numbers presented to IWC were minimums; i.e., even more animals were killed but lost or struck but lost than were reported:

Season	Killed and Recovered	Known killed but lost	Known struck but lost
1973	37	0	10
1974	20	3	28
1975	15	2	26
1976	48	8	35
1977 1/	26	2	77

1/ Spring hunt only.

Document 30 compared the historical records of numbers killed and recovered annually since 1946 with recent data collected by NMFS. Prior to 1970, the annual number killed and recovered averaged 10 whales. Since 1970, the average has been 29 animals per year, and the 1976 level of 48 was the record high for this hunt. Document 30 concluded, and the SC agreed, that recent harvests represented a significant increase in the annual take of bowhead whales by Alaskan Eskimos.

A major problem in assessing the effect of the hunt has been the inability to determine the fate of struck but lost whales. In the past, many scientists on the SC have insisted that the most conservative and hence, "best" view would be to assume that all struck and lost whales subsequently died. To counter this view Tillman presented information in his oral report that one might expect about ½ of these animals to die. This assertion was based upon the personal observations of the NMFS ice crew based at Pt. Barrow that bombs did not go off in about ½ of the 56 whales struck and lost there during the spring 1977 hunt.

These data were utilized by the SC to estimate the minimum number of animals removed from the stock in recent seasons. To the number killed and recovered each year were added the known number struck but lost. Assuming that the stock held constant at its current estimated level of 1000, the SC was able to determine recent removal rates:

Season	Estimated Removals	Removal Rate(%)
1973	42	4.2
1974	37	3.7
1975	40	4.0
1976	74	7.4
1977 1/	67	6.7

1/ Spring hunt only

Overall, the average removal rate was on the order of 5% (including the spring 1977 hunt), the figure reported in the SC report. In detail, removals were on the order of 4% until 1976. The incomplete 1977 season is already an increase over past years due to the extraordinarily high number of struck but lost whales. It should be re-emphasized that all these estimates are minimums since the struck but lost data are minimums.

Document 30 attributed the observed increase in removals to increased whaling effort. For example, the total number of crews participating in the spring hunt at 6 major whaling villages went from 46 in 1974 to 86 in 1976. These data were obtained from NMFS scientists at Barrow and Pt. Hope and from long-term, trustworthy sources in other villages. The increased effort is probably attributable to the increasing affluence of Eskimos, particularly at Barrow, and the inexperience of new captains and crews undoubtedly exacerbates the struck but lost problem.

Deliberations of Scientific Committee

In deliberating on the effect of the Eskimo hunt upon the bowhead whale stock, the SC has always been most concerned with and has placed the greatest weight on the catch statistics submitted by NMFS. This was true of the 1977 meeting as the SC reacted with shock at 1976's record high kill of 56 (48 killed and recovered plus 8 known killed but lost) and 1977's extraordinarily high number of struck but lost

whales, 77, giving a 3:1 loss ratio as opposed to the 1:1 ratio of past seasons.

Of greatest concern to the SC has always been the increasing number of whales which are struck but lost. Moreover the SC has, for the most part, given NMFS the benefit of the doubt in receiving the loss data and has not made an issue of the fact that these are minimums. As early as 1972, the SC urged the U.S. to take steps to reduce waste due to lost whales, and every year since then it either requested further information on the status of the bowhead stock, expressed concern over the high loss rates, or else recommended that steps be taken to limit this expansion.

Of second importance at the 1977 meeting were the estimates of initial abundance provided by NMFS. These gave the first factual means of evaluating the probable impact of the Eskimo hunt. As previously noted, removal rates (incorporating estimates of the number struck and lost which likely die) in recent seasons have been on the order of 5%. The maximum net recruitment capability of baleen whale stocks is thought to be on the order of 4-5%, with conservative scientists tending toward the lower figure (or even lower values). Hence, the SC believed that it was extremely unlikely that the bowhead whale stock would be capable of increasing its numbers given the currently estimated removal rates. Moreover, since the stock apparently did not increase in the years prior to 1970 when the average annual removal was 20 (10 killed and recovered plus 10 struck and lost which die; Rice, 1974) or a 2% removal rate, several SC numbers believed that the numbers of bowhead whales were declining.

Of third importance at the 1977 meeting was Mitchell's estimate of initial stock size. This gave some idea of the degree of endangerment of the stock; i.e., being at roughly 10% of initial size places it well into the Protection Category which begins at 40-50% of initial size.

The SC was appalled that the removal rate had increased to 5% (and beyond in the past two seasons) in such an endangered stock. The SC indicated that, in applying the criteria of the New Management Procedure, a 5% removal rate was allowed only in the best of circumstances that is, 5% is only allowed for stocks in the Initial Management Category whose boundary ends at 80% of initial stock size. Hence 5% was judged not to be a reasonable rate for a stock at 10% of its initial size.

Given the above stock assessment, the SC was extremely disappointed that the U.S. had not undertaken regulatory measures to reduce the losses of whales nor to limit the expansion of the fishery. Moreover, the results of the spring 1977 hunt proved how ineffectual U.S. attempts were in obtaining voluntary reductions from the Eskimos. Moreover, due

to the legal problems, the U.S. delegation was not able to give assurances to the SC that anything could be done to alleviate the problem in 1978. It was not the U.S. failure to act on the 1976 IWC resolution which prompted the SC recommendation, but rather our inability to guarantee that regulations would be imposed in the coming season. The SC perceived then that the political as well as the population situation warranted an international ban on the aboriginal hunting of this species.

Continued Native Harvest

The SC cited the risk of a setting a catch quota for a small stock subject to large environmental fluctuations as the reason for establishing a moratorium on the bowhead whale (Annex L to SC Report). In Tillman's opinion, this is less of an issue than is the problem of struck and lost whales. A small kill on the order of 10 whales (historical level prior to 1970) probably would be supportable by the stock and still allow it to increase. However, additional losses probably could not be sustained nor would the SC accept them at this time. The 1977 recommendation that the shoulder gun be banned was prompted by this long term concern over losses.

If the U.S. decides to allow a small harvest to continue, all possible means, including gaining the cooperation of Eskimos, must be used to eliminate or severely reduce the losses attendant to the hunt. Such a course of action is mandated not only by the current status of the bowhead stock but also if the U.S. is to retain its credibility in the SC. One possible measure would be to establish a set number of takings, i.e. kills plus struck whales which are lost.

THE 1976 CATCH OF BOWHEAD WHALES (BALAENA MYSTICETUS) BY ALASKAN ESKIMOS, WITH A REVIEW OF THE FISHERY, 1973 - 1976, AND A BIOLOGICAL SUMMARY OF THE SPECIES.

BY

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CONTENTS

PART I

THE 1976 CATCH OF BOWHEAD WHALES (BALAENA MYSTICETUS) BY ALASKAN ESKIMOS.

INTRODUCTION

The bowhead whale, Balaena mysticetus, is found in Arctic and northern subarctic waters. Its numbers were greatly reduced over a period of about 300 years, initially in the European Arctic and then in the eastern Canadian Arctic and the Okhotsk Sea. Commercial whaling for bowheads began in the Chukchi and later in the Beaufort Seas during the mid-1800s; the last reported voyage occurred in 1916 (Bower and Aller, 1917) when the steamer Herman and the auxiliary whaling schooner Belvedere sailed north in the spring from San Francisco and Seattle, respectively, returning that autumn with some whale products. Some of the Arctic Alaskan trading companies continued to deal in whalebone for a few more years into the early 1920s. These animals have been completely protected from commercial whaling by the International Convention for the Regulation of Whaling since 1946, and subsequently, by the U.S. Marine Mammal Protection Act (MMPA) of 1972 and the U.S. Endangered Species Act (ESA) of 1973. However, aboriginal whaling is still allowed.

The bowhead whale, also known as the Greenland right whale and the polar whale, is a large cetacean that grows to about 18.3 m (60 feet) in length. It is black or dark gray in color, often marked with white on the chin and underside. Instead of teeth its mouth contains about 600 baleen plates that strain from the water the zooplankton upon which it feeds. It has a very large head approximately one-third the length of the body, and takes its name from the highly arched shape of its mouth.

The bowhead whale of the western arctic inhabits waters extending from the northern Bering Sea in the winter, to the northern Chukchi and Beaufort Seas in the summer. The animal is found along the loose edges of the ice pack and moves northward as the ice recedes in the spring and southward as it extends in the winter. The bowhead's spring migration route passes between St. Lawrence Island and the Chukchi Peninsula, through Bering Strait and along the northwest Alaskan coast, then through the Beaufort Sea to the Banks Island region and the MacKenzie River delta. In autumn, the whales migrate westward along the north coast of Alaska to the vicinity of Wrangel Island, where they turn southward along the coast of the USSR to the northern Bering Sea. During its spring migration, the bowhead is usually seen singly or in pairs, and often in the company of belukhas or white whales (*Delphinapterus leucas*). During its autumn migration, these animals are frequently seen in groups containing up to 50 members.

Historically, maritime Eskimos established their villages at locations where points of land provided access to the bowheads during their migrations. Several villages participate in the spring hunt, but because the whales cross the Chukchi Sea to the coast of the USSR in autumn, only a few villages along the north coast of Alaska hunt them at that time. Residents of the two St. Lawrence Island villages (Gambell and Savoonga), and the mainland villages of Wales, Kivalina, Point Hope, Wainwright, and Barrow engage in spring whaling. Ice conditions east of Barrow do not permit spring whaling by residents of Nuiqsut or Kaktovik (Barter Island), but, these people participate in the autumn hunt as do the Barrow whalers. The locations of Alaskan whaling are shown in Figure 1.

The hunting of bowhead whales for subsistence has been a vital part of Eskimo life for at least 3,500 years (Oswalt, 1967). Present day whaling is conducted by the Eskimos of St. Lawrence Island, the Siberian coast and the Arctic Alaskan coast using a combination of traditional and modern equipment and techniques.

THE PROBLEM

Because of its isolation in an arctic environment, the bowhead whale has received little biological research effort. An expanding Eskimo harvest of this species and the impending development of the oil resources of the Alaskan continental shelf, however, may be critical factors in the survival of the bowhead whale population.

Reliable information on the natural history, numbers of animals, and migratory patterns with respect to the bowhead population is not now available for proper evaluation of the biological effect of the Eskimo harvest and of the potential effect of oil spills.

RESEARCH OBJECTIVES

The objectives of current research are to obtain the information necessary for determining the status of the bowhead whale, the impact of the Eskimo fishery on population size, and the effect that oil exploration and exploitation might have upon this species.

METHODS

Observers monitor the harvest during the spring whaling season at Point Hope and Barrow from approximately 20 April to 7 June, and during the autumn whaling season at Barrow from about 15 September to 30 October. They visit the whaling camps as often as possible and gather information on the number of bowheads sighted, killed and recovered, and struck but subsequently lost. When a whale is taken, the biologists attempt to obtain measurements, collect specimen material for sex and age determination, and take photographs. In addition, they make observations of whaling methods and equipment as a first step toward determining if it is possible to reduce the number of whales struck but not recovered.

In 1976, National Marine Fisheries Service (NMFS) research was expanded with funding from the Outer Continental Shelf Environmental Assessment Program (OCSEAP), to obtain data on the abundance, distribution, and movement of bowhead whales. Aerial surveys are being conducted to obtain information on offshore distribution and migration, and ice-based observation stations have been established to obtain 24-hour counts on the numbers of whales using near-shore leads during the spring migration. Although

data collected by the OCSEAP study is contained in periodic reports published by that program, information pertinent to the harvest is included in this report.1/

SPRING WHALING

Whaling Villages

We collected information at Point Hope and Barrow and indirectly learned of whaling activities at other villages from various sources. Mr. Milstead Zahn, NMFS, Juneau, and Alaska Department of Fish and Game personnel, John J. Burns, Fairbanks, and Carl A. Grauvogel, Nome, supplied information from St. Lawrence Island. Toby Anungazuk, Alaska Department of Fish and Game, Wales, supplied information about whaling at that village. The Reverend Clinton Swan provided information on whaling at Kivalina.

St. Lawrence Island: The whaling season began on St. Lawrence Island about 1 April and ended approximately 20 May. About nineteen crews from Gambell and at least three crews from Savoonga actively whaled during the spring. The first whale harvested by St. Lawrence Island crews was taken 21 April One bowhead was taken by Gambell whalers and seven whales were reported taken by Savoonga crews (Table 1). One of the latter was a stinker, a harpooned whale that died but was not recovered until several days later. Five additional whales were reported struck but lost off St. Lawrence Island. The bowhead whaling season here ends when conditions become favorable for walrus (*Odobenus rosmarus*) hunting, and although whaling gear is carried in the boats, few bowheads are taken after the hunting of walrus has begun. The people of Gambell and Savoonga share their whale catch each year.

One whaling captain from Savoonga reported that during the whaling season he believed that most of the whales passed north in the morning between the hours of 0500 and 0800, and that only a few traveled north throughout the day. He also reported that an unusually large number of bowheads were observed

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1/ Fiscus, Clifford H., Howard W. Braham, and Willman M. Marquette. 1976. Distribution and abundance of bowhead and belukha whales in the Beaufort and Chukchi Seas. In: Environmental Assessment of the Alaskan Continental Shelf, Principal Investigator's Reports, April-June 1976, Volume 1, pp. 68-84.

migrating northward in the spring of 1976.

Wales: Two crews were active during the spring of 1976 at the village of Wales. No whales were taken, and none was struck and lost. The period of whaling approximated that of Point Hope, although the exact dates are not known.

Kivalina: Three crews actively whaled at Kivalina during the spring of 1976. Whales were neither taken nor struck. The period of whaling at Kivalina approximated that of Point Hope, although the exact dates are not known.

Point Hope: The whaling season was begun 10 April when four crews went out on the ice, and ended 28 May when the ice became unsafe. NMFS observers were stationed in the village from 28 April until 1 June to monitor the harvest.

Fourteen whaling crews at Point Hope took twelve whales in 1976 and biological information was collected by NMFS observers from eleven (Table 1). Eight of the whales were young animals less than 8.9 m (29 feet, 2 inches) in length, and four were older animals 10.2 m (33 feet, 6 inches) or over in length. The largest whale taken at Point Hope was 14.7 m (48 feet, 2 inches) in length.

During the 1976 season 235 bowhead whales were sighted at Point Hope (Table 2). Bowheads taken by the whalers were included in the total and every effort was made to eliminate duplicate reports of sightings. Because other whales may have been seen by crew members and not reported, the 235 sightings represent a minimum number of bowheads seen at Point Hope.

Although no whales were reported killed and lost at Point Hope, 12 were struck and lost there. However, an enforcement division patrol conducted by the Alaska Department of Fish and Game observed five dead bowhead whales in the vicinity of Point Hope in mid May. This report indicates that apparently five of the 12 animals that were struck and lost subsequently died of their wounds. The number of whales killed by Point Hope whalers therefore includes 12 that were recovered and five not recovered by the hunters, a total of 17 whales.

Wainwright: Eight whaling crews were reported to be active during the spring of 1976 at the village of Wainwright. Three whales were taken but information was not received on animals that may have been struck and lost. The whaling

Table 1.--Biological features of bowhead whales taken during spring 1976.

Area and date	Length (centimeters)	Sex	Remarks
St. Lawrence Island-Gambell			
--	--	-	One taken, no data available
Savoonga			
--	914[1/]	F	--
--	1067[1/]	M	--
--	610[1/]	M	--
--	762[1/]	M	--
--	914[1/]	M	--
--	853[1/]	M	--
Kivalina	--	-	None taken
Point Hope			
23 April	792[1/]	-	--
1 May	1021	M	--
2 May	1321	F	--
2 May	1120	M	--
2 May	853	F	--
3 May	1468	M	--
3 May	846	F	--
3 May	848	F	--
6 May	825	F	Ingutuk. Stinker.
7 May	889	F	--
9 May	808	F	--
14 May	762	M	--
Wainwright			
--	--	-	One taken, no data available
4 June	--	-	--
4 June	--	-	--
Barrow			
2 May	750[2/]	M	--
5 May	1144	M	--
6 May	796	-	--
6 May	1136	-	--
6 May	750	F	--
9 May	1235	M	Stinker
11 May	980	M	Stinker
12 May	1370	M	Stinker
14 May	1070	M	Stinker
15 May	1100	M	--
15 May	685[2/]	F	--
17 May	854	F	Ingutuk
19 May	1158	F	Stinker

1/ Estimate of length in feet was provided by the Eskimos.
2/ Length based on measuring segments of butchered whale.

Table 2.--Sightings of bowhead whales, spring 1976.

Date	Location: Point Hope	Location: Barrow[1/]
10-23 April	15	0
24 April	-	0
25	-	5
26	-	0
27	-	0
28	4[2/]	0
29	0	17
30	25	17
1 May	107	20
2	7	9
3	5	2
4	0	0
5	7	20
6	13	35
7	8	9
8	0	5
9	9	2
10	0	1
11	0	0
12	0	0
13	12	17
14	5	5
15	0	14
16	3	29
17	3	35
18	0	61
19	0	1
20	0	0
21	3	4
22	3	19
23	6	0
24	0	9
25	0	1
26	0	6
27	0	0
28	0	0
29	0	0
30	0	0
31	0	1
1 June	0	1
2	-	1
Totals	235	346

1/ Data from Fiscus, Braham, and Marquette, 1976. See footnote 1/ (corrected figures provided by H. Braham, pers. comm.).

2/ Observed from aircraft on flight from Barrow to Point Hope.

period at Wainwright approximates that of Barrow.

Barrow: The whaling season began approximately 20 April, 1976 and ended 2 June when the ice became unsafe for travel. Two observers were stationed at the Naval Arctic Research Laboratory (NARL), Barrow, from 22 April to 3 June. In addition, an OCSEAP crew of four people was stationed on the ice at the edge of the lead to make observations of bowhead whales and other marine mammals throughout the whaling season.

The number of whaling crews actively engaged in whaling varied almost daily, but approximately 36 of them operated at Barrow some time during the season. Thirteen whales were taken and recovered during the spring season. Five of the thirteen whales recovered were stinkers, the highest number recorded during a single season since the NMFS began monitoring the harvest. In addition, 18 bowheads were reported struck and lost, and seven more were killed and lost. Two additional bowheads may have been killed and lost, which would bring the total to 22. These animals were sighted from the air by OCSEAP scientists (H. Braham, pers. comm.). One dead whale was sighted 24 May floating among the ice floes 46 km (25 miles) south of Barrow and about 28-37 km (15-20 miles) offshore. On 22 May, the aerial survey crew observed 34 polar bears (*Ursus maritimus*) on the ice feeding upon what appeared to be a whale carcass, judging from the amount of debris in the area and the size of the body.

Some data were obtained on each of the butchered whales (Table 1). Body lengths of the whales taken ranged from 6.8 to 13.7 m (22 feet, 6 inches to 45 feet). The muktuk (skin and blubber), flukes, and baleen of a stinker can be salvaged but the remainder must be discarded as inedible. Normally, the crew responsible for the death of a stinker can be identified from marks on the harpoon or from bomb particles embedded in the whale. If so, the crew that recovers the animal shares the carcass with the crew that killed it. Otherwise, a stinker belongs to the recovering crew.

Whaling Methods

The method presently used by Alaskan Eskimos to take whales has evolved from ancestral methods and the adoption of commercial whaling gear and methods introduced by Yankee whalers in the last century. Van Stone (1958) described the era of

commercial bowhead whaling in Alaskan waters. The most recent description of the development of current Eskimo whaling methods is that of Durham (1974). Van Stone (1962) describes the traditional method of marking and cutting shares from a whale carcass at Point Hope, which, with some modification, is still in use. A similar though much simplified method of marking and cutting shares from whales is used at Barrow.

A description of whaling crews and current whaling methods and equipment employed in the fishery was presented in previous reports on the Eskimo harvest of bowhead whales (Fiscus and Marquette[2/], and Marquette, 1976). The cost of maintaining and replacing whaling equipment which is becoming increasingly expensive, is borne primarily by the whaling captains. Whaling gear used by the 14 crews at Point Hope is listed in Table 3.

Four new umiaks (skin boats) were constructed during the 1975-76 winter and used for spring whaling at Point Hope in 1976. One captain stated that he paid $700 for the boat frame, and the bearded seal (Erignathus barbatus) skins used to cover it cost an additional $200. One umiak was constructed at Kotzebue and transported to Point Hope in early spring by snowmobile and sled, a 4-day trip. Although all umiaks are of the same general dimensions and appearance, slight variations in materials and construction techniques make each distinctive.

In 1976 the price of a shoulder gun at the Pt. Hope Store was $647, darting guns were $367.05 each, and a harpoon cost $33.25. In addition, a village tax of 2 percent was levied on all store items for the first time in 1976. At least three villagers own block and tackle sets capable of hauling whales out of the water onto the ice for butchering. Because the lines of one set were old and weak and broke frequently during use, much time was spent repairing them, which slowed the butchering process considerably. Each set of block and tackle is valued at about $1,000, and use of his equipment to remove a whale from the water entitles the owner to a share of that animal.

2/. Fiscus, Clifford H., and Willman M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska, 1974. Nat. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, Washington. Processed report, 23 pp.

Table 3.--Type of equipment used by whaling crews at Point Hope, Alaska, spring 1976. Each horizontal line refers to the equipment of one crew.

				Darting gun		Floats		
	Boat (Umiak)	Outboard motor	Shoulder gun	With harpoon	Without harpoon	Large plastic	Small plastic	Sealskin
	1	0	1	1	0	0	1	1
	1	0	1	1	1	0	1	1
	1	0	2	1	1	1	1	0
	1	1	2	1 1/	1 2/	1	1	0
	1	0	0	1	1	1	1	0
	1	0	0	1	1	1	1	0
	1	1	2	1	1	1	1	0
	1	0	1	1	1	1	1	0
	1	0	1	1	1	1	1	0
	1	0	1	1	0	1	1	0
	1	1	0	1	1	1	1	0
	1	0	1	1	1	1	1	0
	1	1	1	1	1	1	1	0
	1	0	0	1	1	1	1	0
Total	14	4	13	14	12	12	14	2

1/. Lost taking whale on 3 May, replacement purchased.

2/. Lost taking whale on 3 May.

In Barrow, large plastic floats (38 to 51 cm; 15 to 20 inches) that are attached to the harpoon lines to impede the whale's escape were selling for $42.50, and the small floats (30 to 36 cm; 12 to 14 inches) that are attached by a line to the darting guns to keep them from sinking, were priced at $16.75 each. At least two individuals own block and tackle sets at Barrow.

Whaling Effort

More crews were engaged in bowhead whaling in 1976 than in 1975. The number increased from 13 to 14 at Point Hope, from 4 to 8 at Wainwright, and from 30 to 36 at Barrow. Although a large number of crews are outfitted with whaling gear, the number that actively engage in whaling throughout the season is significantly smaller. At Kivalina only 3 crews were reported to have whaled in the spring of 1976, 2 less than reported for 1975. Two crews were actively whaling at Wales, and 23 were reported to be on St. Lawrence Island in 1976, a figure similar to that of 1975. At least 86 crews were, therefore, engaged in whaling in the spring of 1976.

Since the number of crews hunting at the lead varies daily, we maintained a record of their activities throughout the season in an attempt to evaluate hunting effort (Tables 4 and 5). In 1976, Point Hope crews were at the lead 23 days (66 percent of the time) from 28 April to 1 June. At Barrow, crews were at the lead 31 days (72 percent of the time) from 22 April to 3 June. Weather conditions at Barrow during this period are presented in Table 6.

Whaling effort of the crews at the two villages was evaluated by examining the number of crew-days required to take a whale. Expressed as the number of crews that whaled each day, Point Hope crews whaled a total of 229 crew-days for an average of 6.5 crews per day, and Barrow crews whaled 314 crew-days, an average of 7.3 crews per day during the season. Since 12 whales were taken at Point Hope, 19.1 crew-days were required for each whale recovered. At Barrow, 24.2 crew-days were required to take each of 13 whales during the spring harvest. A comparison of crew-days required to take whales indicates that the Point Hope whalers expended slightly less effort to take whales and hence are more efficient than the whalers at Barrow. Whaling effort required to take whales during a season may indicate differential effects of the climate, ice, and ocean currents on the ability of the whalers to kill and recover bowhead whales.

Although the total number of crews engaged in whaling in the spring of 1976 at Barrow was large, the number that

Table 4 . Whaling effort at Point Hope, Alaska, spring 1976.

Date	Number of crews on lead	Remarks
28 April	0	Lead closed.
29	0	Lead closed.
30	14	Lead opened at 1200 hours.
1 May	14	Lead open.
2	14	Lead open.
3	14	Lead open.
4	14	Lead open.
5	14	Lead open.
6	10	Lead open, several miles wide.
7	12	Lead open, several miles wide.
8	13	Lead open, several miles wide.
9	14	Lead open,; all crews off ice 2400 hours, windy.
10	0	Lead open, windy and rough.
11	8	Lead open, windy and rough.
12	10	Lead open.
13	14	Lead open.
14	12	Lead open.
15	6	Most of lead closed, open on East end.
16	3	Most of lead closed, open on East end, raining.
17	4	Most of lead closed, open on East end, raining.
18	0	Lead open, windy and rough, ice dangerous.
19	0	Lead open, windy and rough, ice dangerous.
20	0	Lead open, windy and rough, ice dangerous.
21	7	Lead open.
22	13	Lead open.
23	13	Lead open.
24	1	Lead open, windy and rough.
25	0	Lead open, windy and rough.
26	0	Lead closed.
27	3	Scattered openings.
28	2	Lead open, windy and rough.
29	0	Lead open, windy, strong current, ice dangerous.
30	0	Lead open, windy, strong current, ice dangerous.
31	0	Lead open, windy, strong current, ice dangerous.
1 June	0	End of season.

Table 5.--Whaling effort at Barrow, Alaska, spring 1976.

Date	Number of crews in lead	Remarks
April		
22	3	Lead opening and closing
23	6	Lead closed
24	0	Lead closed
25	0	Lead closed
26	10	Lead closed
27	0	Lead closed
28	0	Lead closed
29	7	Lead open
30	13	Lead open
May		
1	15	South lead closed, north lead open
2	10	North lead open, windy and rough
3	13	All crews off ice by evening
4	0	Strong offshore wind
5	20	Lead open
6	22	Lead open, windy and rough
7	0	Lead open, windy and rough
8	20	Lead freezing over
9	0	Lead closed
10	0	Lead closed
11	0	Lead closed
12	0	Lead closed
13	10	Variable openings
14	15	Variable openings
15	28	Lead open
16	27	Lead open
17	27	Lead open
18	20	Lead closing
19	10	Scattered openings
20	5	Scattered openings
21	5	Scattered openings
22	5	Scattered openings
23	5	Scattered openings
24	5	Scattered openings
25	2	Scattered openings
26	2	Lead closing
27	2	Lead closed
28	2	Lead closed
29	0	Lead closed
30	1	Ice breaking up
31	1	Ice breaking up
June		
1	2	Ice dangerous
2	1	Ice dangerous
3	0	Season ended

Table 6.--Weather data at Barrow, Alaska, spring 1976.

Date	Temperature (F°) Max.	Min.	Ave.	Average wind velocity (Mph)	Wind direction (degrees)
April					
22	10	-9	1	6.8	090
23	11	5	8	5.3	340
24	10	6	8	8.2	090
25	16	5	10	9.0	100
26	18	4	11	8.2	090
27	15	-1	7	6.1	250
28	14	-12	1	9.6	140
29	19	-6	7	14.3	100
30	23	10	17	12.5	090
May					
1	23	9	16	11.6	080
2	25	15	20	13.2	060
3	28	15	22	18.7	070
4	30	22	26	16.5	070
5	30	16	23	6.3	200
6	27	14	21	13.6	060
7	16	9	13	15.8	060
8	14	6	10	8.6	020
9	13	2	8	8.2	060
10	10	1	6	7.2	060
11	9	3	6	5.7	060
12	14	9	12	11.3	070
13	15	4	10	14.0	070
14	13	4	9	12.5	060
15	15	10	13	12.9	090
16	21	13	17	15.2	080
17	16	9	13	15.6	070
18	11	8	10	12.5	080
19	11	7	9	7.6	290
20	17	10	14	5.4	090
21	15	11	13	10.2	090
22	20	11	16	14.6	080
23	23	19	21	12.1	080
24	27	23	25	12.3	030
25	30	23	27	11.2	020
26	29	19	24	12.4	230
27	25	13	19	9.3	220
28	30	22	26	11.2	020
29	30	25	28	14.0	010
30	35	28	32	11.6	070
31	34	26	30	11.9	110
June					
1	34	23	28	10.0	080

participated at every opportunity throughout the season averaged close to eleven. A daily count of active crews was not obtained because camps were scattered along 25 miles of lead and not all could be reached during a single day. The whaling season lasted about a month and a half at Point Hope and Barrow with the most productive hunting occurring during May.

Utilization

The whales were pulled from the water when possible by means of a block and tackle and then butchered. Thin ice required partial butchering of the animal before it could be hauled from the water, a situation that greatly increased the time spent on this aspect of whaling. Accordingly, the butchering process required from as few as 3 to as many as 30 hours. Parts removed from the animal were taken ashore as soon as possible to prevent loss when the ice shifted.

Most of the meat, muktuk, and blubber were removed from the butchering site immediately after the whale was cut up. Occasionally, however, several days elapsed before all parties hauled off their shares. Remains of the backbone, some ribs and internal organs, and the skull (at Barrow) were generally left on the site. Usually, fewer parts of the whale were left on the ice at Point Hope than at Barrow. At Point Hope, the skull was returned to the sea after the tympanic bullae and lower jawbones were removed, and the latter were taken to the village. At Barrow, the skull (tympanic bullae removed), including jawbones, was usually left at the butchering site. At some butchering sites, mostly at Barrow, blubber was left on the ice. Before the snowmobile era, surplus blubber was used for dog feed. The Eskimo utilizes most of the whale, including the meat, muktuk, baleen, gum tissue (mamaak), flukes, flippers, brains, tongue, intestines, heart, kidneys, epithelium of the liver, the tympanic bullae, and frequently the stomachs (Carroll, 1976).

Other Mammals

In addition to bowhead whales the following species of mammals were observed or reported in 1976 at Point Hope during the spring whaling season.

Belukha	*Delphinapterus leucas*
Bearded seal	*Erignathus barbatus*
Largha seal	*Phoca largha*

Ringed seal	Phoca hispida
Polar bear	Ursus maritimus
Walrus	Odobenus rosmarus

Belukha were observed from 28 April to 22 May at Point Hope. At least two noticeable waves of these animals migrated past the whaling camps. The first occurred from late April to 5 May and the second from 8 to 16 May. A third wave may have occurred in late May. Belukha sighted and taken at Point Hope are given in Table 7.

The whalers do not actively pursue belukha during the bowhead whaling season because they frequently sink quickly and require considerable effort to recover, although they are prized for food. A belukha harvest at this time is incidental to the bowhead whale fishery. Rifles are normally used to kill the animals. It is difficult to obtain data on the belukha because these animals are butchered immediately after they are killed, a process that requires but a few minutes to complete after the animal is hauled onto the ice. Crew members at times eat some of the meat at the whaling camp, but usually take their shares directly home. Measurements were obtained of a fetus that had been abandoned on the ice after whalers had butchered a pregnant female.

Other species killed at Point Hope during the spring whaling season (Table 8) included 77 ringed seals and one largha seal. Two bearded seals were sighted but not killed. A dead floating walrus was found drifting in the lead by the whalers but was not taken. Two polar bears were sighted from an aircraft on a flight from Barrow to Point Hope.

At Barrow, other species killed included two belukha (Table 7) one of which sank and was lost, and four polar bears (Table 9). A total of 328 belukha were sighted: 19 on 16 May, 101 on 18 May, and 208 on 22 May (Table 7). Sightings of belukha at Barrow varied considerably, perhaps due to weather and ice conditions that made observations difficult. Belukha may utilize leads that are farther out than the near-shore leads frequented by whalers, as indicated by OCSEAP surveys[1/]. In addition to 34 polar bears counted feeding upon a large carcass frozen in the ice north of Barrow, other marine mammals observed during aerial surveys of the northeastern Chukchi and western Beaufort Seas by OCSEAP observers from 30 April to 20 June are reported by Fiscus, Braham, and Marquette[1/].

At Wales, three belukha were reported taken by two crews that whaled there during the spring season (Table 7).

Narwhals (Monodon monoceros) have been reported as occasional visitors to Alaskan waters (Geist, Buckley and

Table 7.--Belukha taken or observed at whaling villages in Alaska during spring, 1976.

Location and date	Number sighted	Killed and recovered	Killed but lost	Remarks
Point Hope				
28 April	321	0	0	Observed from aircraft on flight from Barrow to Pt. Hope
1 May	26	0	0	
2	1	1	0	
3	150	1	0	
5	10	0	0	
6	1	0	0	
7	1	1	0	
8	15	0	0	
9	4	4	0	
11	100	0	0	
13	250	0	0	
14	1	1	0	Male 423 cm long, skull taken for MMD collection
16	12	0	0	
17	1	0	0	
22	35	0	0	
Totals	928	8	0	
Barrow 1/				
16 May	19	0	0	
18	101	0	1	Sank
22	208	1	0	
Totals	328	1	1	
Wales				
--	3	3	-	
Totals	3	3	-	

1/ Data combined for harvest and OCSEAP crews.

Table 8.--Mammals other than whales taken or observed at Point Hope, Alaska, spring 1976.

Species	Date	Number sighted	Number killed	Sex	Length
Ringed seal	24 Feb.-7 March		1	M	--
	24 Feb.-7 March		1	M	--
	24 Feb.-7 March		1	-	--
	7-19 March		1	M	118.6
	12-19 April		1	-	--
	12-19 April		1	M	--
	12-19 April		1	M	--
	12-19 April		1	M	--
	16-21 April		1	F	--
	16-21 April		1	M	--
	16-21 April		1	M	--
	16-21 April		1	M	--
	16-21 April		1	-	--
	16-21 April		1	M	--
	16-21 April		1	M	--
	16-21 April		1	M	--
	16-21 April		1	M	--
	16-21 April		1	M	--
	16-21 April		1	M	--
	16-23 April		1	M	--
	16-23 April		1	M	--
	16-27 April		1	M	--
	18 Apr.-2 May		7	-	--
	24-27 April		2	M	--
	24-30 April		1	M	--
	25 April		1	M	--
	30 April		1	M	--
	1 May		1	M	126.9
	1 May		10	-	--
	6 May		10	-	--
	13 May		1	M	123.7
	13 May		1	M	126.0
	16 May		1	M	117.4
	17 May		3	-	--
	27 May		5	M	--
	27 May		1	F	--
	27 May		1	F	126.6
	27 May		1	M	106.6
	27 May		1	F	106.1
	27 May		1	F	102.6
	27 May		1	M	120.8
	27 May		1	M	108.3
	27 May		1	F	101.2
	27 May		1	F	107.0
	27 May		1	M	112.2
	27 May		1	M	112.5

Table 8.--Mammals other than whales killed or observed at Point Hope, Alaska, spring 1976--continued.

Species	Date	Number sighted	Number killed	Sex	Length	Remarks
Bearded seal	1 May	1	0	-	-	
	31 May	1	0	-	-	
Largha seal	1 May	1	1	-	-	
Polar bear	28 April	2	0	-	-	Observed from aircraft on flight from Barrow to Point Hope
Walrus	12 May	1 (dead)	0	-	-	Found floating in lead, not taken

Table 9.--Mammals other than whales killed or observed at Barrow, Alaska, spring 1976.

Species	Date	Number sighted	Number taken	Remarks
Polar bear	14 May	1	0	
	31 May	1	1	
	31 May	1	1	
	31 May	1	1	
	31 May	1	1	
		5	4	

Manville, 1960). An experienced whaling captain at Barrow reported that he sighted a single narwhal in a pod of belukha on 15 May, west of the village. In another unconfirmed report, NMFS observers at Point Hope during the spring of 1974 were informed of a narwhal that had been found dead on the beach north of the village at Pingu Bluff in October or November of 1973. The animal was described as being about the same size as a belukha, with a tusk that protruded from the body approximately 51 cm (20 inches). The tusk had been traded to a non-resident of the village and was not available for examination.

A resident of Barrow stated that he sighted killer (Orcinus orca) and gray (Eschrichtius robustus) whales while travelling to Wainwright by boat during the first week of September. Killer whales apparently appear occasionally in Alaskan arctic waters. Bee and Hall (1956) noted three records (one near Icy Cape, and two near Barrow) of these whales in the area. Banfield (1974) states that they are rare visitors to the Beaufort Sea.

Two incidents of killer whales attacking other cetaceans were reported by Eskimos in 1976. In August 1975, four Point Hope residents on a boat a short distance south of the village observed seven killer whales attacking a young gray whale. They reported that the largest killer whale held the gray by the tail while the others attacked various areas of the gray's body. After a short time the killer whales appeared to abandon the gray, which was almost motionless and bleeding profusely. After remaining almost lifeless for several minutes, the gray began to feebly swim away when the killer whales suddenly reappeared and attacked it again. The gray soon sank from sight and, presumably, died. At Barrow, three residents witnessed three or four killer whales attacking an unidentified cetacean off the coast of that village during this past summer.

AUTUMN WHALING

Barrow: The beginning of the autumn whaling season coincides with the westward migration of bowheads past Barrow to wintering grounds in the northern Bering Sea. In 1976 the whaling season began 26 August, which was unusually early for Barrow, and ended 8 October when the formation of new ice prevented further travel by boat. Weather data for Barrow during this period is given in Table 10. The pack ice remained approximately 104.6 km (65 miles) off the north coast of Alaska during the autumn whaling season. An NMFS observer was

Table 10.--Weather data at Barrow, Alaska, during autumn whaling season.

Date	Temperature (F°) maximum	minimum	average	Average wind velocity (Mph)	Wind direction (degrees)
August					
26	46	34	40	14.2	090
27	41	33	37	10.6	080
28	42	33	38	6.0	100
29	48	33	41	5.8	120
30	43	36	40	6.0	150
31	51	35	43	6.5	100
September					
1	37	34	36	4.4	330
2	37	31	34	4.2	310
3	33	30	32	7.8	300
4	36	28	32	8.6	260
5	35	26	31	6.7	190
6	37	31	34	8.9	160
7	44	33	39	11.1	180
8	34	31	33	9.3	020
9	36	33	35	5.4	070
10	38	32	35	8.7	120
11	48	33	41	13.5	120
12	34	30	32	11.8	100
13	33	31	32	11.4	080
14	36	32	34	17.3	070
15	35	33	34	13.9	060
16	35	32	34	6.9	060
17	35	31	33	10.4	100
18	35	30	33	12.4	100
19	33	29	31	8.3	080
20	31	23	27	9.2	080
21	46	31	39	15.2	190
22	39	32	36	10.4	230
23	34	29	32	14.9	060
24	31	27	29	14.6	070
25	30	27	29	14.9	070
26	33	30	32	7.8	050
27	32	28	30	9.3	080
28	31	27	29	18.5	040
29	29	22	26	19.9	050
30	22	18	20	19.5	070
October					
1	24	19	22	18.1	080
2	27	18	23	15.2	090
3	26	23	25	15.2	040
4	25	23	24	16.4	040
5	27	23	25	18.4	070
6	28	22	25	15.1	070
7	28	21	25	7.7	070
8	26	21	24	14.6	230
9	24	4	14	16.6	240
10	19	0	10	15.5	220

stationed at NARL from 11 September to 14 October.

Autumn whaling differs in several ways from spring whaling. Wood or aluminum boats 5.49 to 7.62 m (18 to 25 feet) in length are used instead of skin covered boats. The crews often must venture several miles out to sea to locate the whales. The boats are powered by large outboard or inboard motors; noise made by these motors apparently does not frighten the animals in the autumn as it does during the spring hunt. As in the spring, darting and shoulder guns are used in the autumn to kill the whales. However, since the migrating whales are usually hunted in the open sea during the autumn, they are unable to escape easily by swimming under nearby ice floes as they frequently do in the spring. The whalers are therefore able to pursue them for a longer time, continuing to fire bombs into them until they die. For example, one captain reported that after firing all the bombs that he had with him (17) at one whale, he finally killed it with a lance.

Twelve crews engaged in autumn whaling at Barrow killed and recovered ten whales. An eleventh whale was killed but abandoned because of rough seas and an insufficient number of boats to assist in safely towing the carcass to shore some 46 km (25 miles). The whalers reported that most of the whales were taken about 37 km (20 miles) north of Point Barrow. Fifteen to thirty-two hours were required to tow the whales to shore near the village. Data obtained on whales that were killed and recovered is presented in Table 11. Although the whalers prefer to kill the small whales that are reported to follow the earlier migrating large animals, the ten whales taken this autumn were all large and measured from 13.20 to 17.30 m (43 feet, 4 inches to 56 feet, 9 inches) in length. This year is the first in which bowheads have been reported taken in August at Barrow.

Nuiqsut: Three crews actively whaled during the autumn of 1976 at the village of Nuiqsut. A fourth crew could not join the hunt because of a malfunctioning motor. Whales were not taken, and information was not received on animals that may have been struck but lost.

Kaktovik: Seven whaling crews were active during the autumn of 1976 at the village of Kaktovik on Barter Island. Two bowheads were killed by Kaktovik crews, but information was not received on whales that were struck and lost.

Table 11.--Biological features of bowhead whales taken during autumn 1976.

Area and date	Length (centimeters)	Sex	Remarks
Barrow			
28 August	1650 1/	M	--
30 August	1630 1/	M	--
3 September	1620 1/	M	--
3 September	1650 1/	M	--
3 September	1730 1/	F	--131 cm fetus collected.
10 September	1600	F	--Ingutuvak 2/
20 September	1430	F	--
20 September	1408	M	--
20 September	1525	M	--
21 September	--	-	Lost due to high seas.
7 October	1320	M	--
Kakotvik			
20 September	1371 1/	M	--
27 September	914 1/	-	--
Nuigsut	--	-	None taken

1/. Length estimated by natives.
2/. Whales that are especially fat are designated by the Eskimos as Ingutuk if small and Ingutuvak if large.

SUMMARY

Details concerning the bowhead hunt in 1976 were:

Location	Season	Butchered No.	Killed and lost no.	Struck and lost no.
Gambell	Spring	1	0	0
Savoonga	Spring	7	0	5
Wales	Spring	0	0	0
Kivalina	Spring	0	0	0
Point Hope	Spring	12	0	12
Wainwright	Spring	3	0	3
Barrow	Spring	13	7	18
Barrow	Autumn	10	1	0
Nuiqsut	Autumn	0	0	0
Kaktovik	Autumn	2	0	0
Total		48	8	35

The fact that a whale is struck and lost does not necessarily mean that it has been fatally injured. Some whales harpooned with the darting gun escape when the line breaks, and others hit with a missile from the shoulder gun escape if the bomb fails to explode. Some of these animals may die and some may recover.

In 1976, 35 whales were reported struck and lost and 8 were reported killed and lost for a total of 43 struck and lost. It should be noted, however, that since these data are obtained from statements made by the whalers, or rarely from the observations of investigators, they represent a minimum known number of animals struck and lost.

At the two villages (Point Hope and Barrow) where NMFS observers were stationed in the spring of 1976, 25 whales were killed and recovered compared to 30 struck and lost. At Barrow 25 whales were struck and lost, of which 7 were reported killed and lost. Since 13 whales were killed and recovered, almost 2 of the animals were struck and lost for each one recovered. At Point Hope 24 whales were struck, of which 12 were killed and recovered and 12 were struck and lost. The Point Hope data are considered reasonably complete, whereas those for Barrow are incomplete due to the greater geographic dispersion of whalers in that locality.

PART II

A REVIEW OF THE HARVEST, 1973 - 1976

AND A BIOLOGICAL SUMMARY OF THE SPECIES.

INTRODUCTION

The current investigation of the subsistence harvest for bowhead whales conducted by Alaskan Eskimos was begun by the NMFS in 1973. The principal objective of the research is to obtain population and biological data necessary to determine the status of the bowhead in the Bering, Chukchi, and Beaufort Seas, and to evaluate the effect of the harvest on these whales. A secondary objective is to evaluate the effect that oil exploration and exploitation might have upon this species. Knowledge obtained from this research will provide the basis for determining whether protective measures are needed for this endangered whale as provided for by the MMPA of 1972 and the ESA of 1973.

Maritime Eskimos of arctic Alaska have conducted a subsistence hunt for bowhead whales since before 1800 B.C. (Oswalt, 1967). Little is known about past harvests of bowheads by these people because they normally do not keep records of their catch. Whaling has been the economic and social basis of Eskimo culture for centuries.

Commercial whaling for bowheads began in the Arctic Ocean in 1848 when the vessel _Superior_, commanded by Captain Roys, became the first whaler to pass through the Bering Strait in search of these animals (Harmer, 1928). Others followed Roys and in 1870, 487 whales were taken (estimated on the basis of whalebone production by Rice, 1974). Although 309 whales were reported taken in 1893 (Allen, 1942), the fishery declined rapidly after that and commercial whaling ended early in the 20th century.

Following severe depletion of the bowhead whale population in the western Arctic Ocean by commercial whalers, it received complete protection from further exploitation by the International Conventions for the Regulation of Whaling of 1931, 1937, and 1946. Aborigines, however, have been allowed to continue taking the whales for subsistence.

Paragraphs 1, 6, and 7 of the Schedule to the International Whaling Convention of 1946, revised in 1975, are applicable to the harvest of bowhead whales by aborigines. Paragraph 1 includes _Balaena mysticetus_, the bowhead, in the definition of "right whale." Paragraph 6(c) classifies right whales as a Protection Stock which is defined as follows: "A Protection Stock is a stock which is below 10 percent of MSY stock level. There shall be no commercial whaling on species or stocks whilst they are classified as Protection Stocks." However, paragraph 7 specifies that "...the taking of gray or right whales by aborigines or a Contracting Government on behalf of aborigines is permitted but only when the meat and products of such whales are to be used exclusively for local consumption by the aborigines."

The MMPA (Sec. 101b) provides that any Indian, Aleut, or Eskimo "who dwells on the coast of the North Pacific Ocean or the Arctic Ocean" may take bowhead whales for subsistence or for the purpose of creating authentic articles of handicraft, if not accomplished in a wasteful manner. The MMPA further allows the Secretary (of Commerce) to prescribe protective regulations if a species subject to such aboriginal taking is determined to be depleted. The ESA (Sec. 10e) allows Alaskan Indians, Aleuts, and Eskimos the same privileges as does the

MMPA. If, however, the taking of an endangered species affects it "materially and negatively," the ESA allows the Secretary (of Commerce) to prescribe protective regulation for that species.

The first studies on bowhead whales by the Marine Mammal Division (MMD), then the Marine Mammal Biological Laboratory, were carried out by Dale W. Rice3/ in 1961 and 1962. In 1973, through a contract with the University of Southern California, the MMD of the Northwest and Alaska Fisheries Center (NWAFC) supported Dr. Floyd Durham's studies of the bowhead whale, which he had begun in 1961. Since 1974 the MMD has stationed scientists at the two most important whaling villages (Point Hope and Barrow) to monitor the hunt and gather catch statistics and biological data, except in 1975 when the Barrow studies were contracted to the University of Alaska. Beginning in September 1975, the MMD has also participated in the OCSEAP study to evaluate the possible effects of oil development related activities on bowhead whales. Information obtained by monitoring the harvest, together with base-line data collected as a result of the OCSEAP studies, will provide the data necessary to provide a continuing evaluation of the population status of these whales.

METHODS

Information on the Eskimo harvest of bowhead whales is collected by biologists stationed at Point Hope and Barrow, the two major whaling villages, during the whaling seasons. They visit the whaling camps as often as possible and gather information on the number of bowheads sighted, killed and recovered, and struck but subsequently lost. Every effort is made to obtain morphological measurements, biological specimens for sex and age determinations, and photographs of each whale taken by the Eskimos. In addition, the biologists observe whaling methods and equipment as a first step toward determining if it is possible to reduce the number of whales wounded but not recovered.

The collection of biological data and specimen samples by NMFS observers is largely subject to voluntary cooperative

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3/ Rice, Dale W. 1964. Eskimo whaling in Arctic Alaska. U.S. Fish and Wildlife Service, Marine Mammal Biological Laboratory, Bureau of Commercial Fisheries, Seattle, WA. Typewritten report, 23 pp.

efforts by the whalers. In addition, since recovered animals must be cut up and taken ashore as soon as possible because of the constant danger of shifting ice, the whalers do not tolerate any significant delay of their activities. For this reason, the observers attempt to arrive at the scene of a kill before the carcass has been removed from the water. If the investigators are present for the entire butchering process it is often possible to obtain much of the desired biological information.

In 1975, research on bowhead whales was expanded with funding from the OCSEAP. Aerial surveys and an ice-based station were employed to obtain data on the distribution, migration, and abundance of bowheads.[1/] Aerial surveys were conducted from the Naval Arctic Research Laboratory, Barrow, Alaska. Depending upon the cloud ceiling, surveys were flown at altitudes of 200 to 2,000 feet, with near and offshore leads surveyed. Visual estimates were made, and photographs were taken to verify species and numbers of animals sighted. The ice-based station was established on shorefast ice approximately eight miles northwest of Barrow. A 24-hour watch was maintained, when ice conditions permitted, and the number of bowhead whales sighted was recorded. Sightings by Eskimos were also obtained; these sightings were screened to ensure that they were not duplicates of the ice station crew sightings. Data thus obtained will provide information on the distribution, migration, and abundance of the bowhead population in the Bering, Chukchi, and Beaufort Seas.

DISTRIBUTION AND MIGRATION

The bowhead whale inhabits arctic and subarctic waters in four principal areas: (1) from Spitzbergen west to east Greenland, (2) in Davis Strait, Baffin Bay, James Bay, and adjacent waters; (3) in the Bering, Chukchi, Beaufort, and East Siberian Seas; and (4) in the Okhotsk Sea. They inhabit the loose edge of the ice pack and migrate with ice movements. At peak population the bowhead whale was considered circumpolar in distribution (Tomlin, 1957), retreating to the north Atlantic and Bering Seas only in winter.

During the spring migration northward the bowheads follow extensive leads in the ice that are oriented in a southwest to northeast direction (Fay, 1974). The leads pass close to prominent land points such as Wales, Point Hope, and Barrow (Shapiro and Burns, 1974). Timing of the migration is no doubt

related to ice conditions, and movements northward in the spring and southward in the autumn are fairly regular through the years. Bailey and Hendee (1926) reported that the first bowheads were seen at Wales in the latter part of April. According to Foote4/, the earliest known date for the arrival of whales at Point Hope within the past few decades was 19 March, but during the 1950's they were sighted usually during the first two weeks of April. Johnson, et al. (1966) reported that the first bowheads arrived at Point Hope on 11 April in 1960 and on 13 April in 1961. The earliest known date that bowheads have appeared at Barrow was reported by Brower (1954) to be 29 March. Durham5/ states that the first run usually arrives at Barrow during the latter part of April. The spring harvest generally ends late in May, although bowheads have been observed passing Barrow during June when the ice is unsafe for hunting.

The Eskimos of Point Hope and Barrow general recognize three distinct runs of whales past their villages during the spring migration (Brower6/, Foote4/, and Nelson, 1969). According to Durham5/ as many as four runs (or waves) of bowheads occur. The first run passes Point Hope in early April and Barrow in late April, which in some years may not be noticed due to ice conditions which prevent the whalers from going out. Our observers have also noted three distinct runs past Point Hope and Barrow and possibly a fourth. Whales making up the first two runs are usually small animals of both sexes, and many of them are the size that Durham5/ would call yearlings, ranging in length from 6.7 to 7.9 m (22 to 26 feet). Whales making up the third run include large males and females with calves. Since observations are affected by weather and ice conditions, more information must be gathered on migration waves before definite conclusions can be drawn.

4/ Foote, Don Charles. 1964. Observations of the bowhead whale at Point Hope, Alaska. McGill University, Montreal, P.Q., Canada. Unpublished manuscript. January. pp. 1-78.

5/ Durham, Floyd E. 1972. Biology of the bowhead whale (*Balaena mysticetus* L.) in the western Arctic, University of Southern California, Los Angeles. Unpublished manuscript.

6/ Brower, Charles D. 1920-26. The Northernmost American-an Autobiography, 2 Vols. Copy in Naval Arctic Research Laboratory Library, Barrow, Alaska.

Based upon sightings (Table 2), three fairly distinct groups or runs of bowhead whales migrated past Point Hope and Barrow during the spring of 1976. At Point Hope, an early run apparently occurred during mid-April, a second from 28 April to 9 May, and a third from 13 to 23 May. Observations were limited during the last ten days of May because of inclement weather and the water currents that created dangerous ice conditions. Three runs of whales also passed by Barrow, the first of which occurred from 25 April to 3 May, the second 5-10 May, and the third from 13 to 31 May. The third group that passed Barrow may actually have been two separate runs (13-19 and 21-26 May), but adverse weather and ice conditions restricted observations during this period.

The above data are weak and more information must be gathered on migrations before definite conclusions can be drawn. Certainly, the bowhead whale is dependent on leads or recently fractured ice containing thin spots through which it can surface for air. Leads far offshore might allow whales to migrate unobserved, and poor visibility on windy days would also limit sightings.

Many species of animals and birds migrate in a series of waves from wintering to summering grounds. Rice and Wolman (1971) describe the seasonal migratory cycle of the gray whale, which exhibits temporal segregation by age, sex, and reproductive status. Similar segregation has been reported in the humpback whale, Megaptera novaeangliae, by Dawbin (1966).

THE HARVEST

The method presently used by Alaskan Eskimos to take whales has evolved from traditional methods and the adoption of gear and techniques introduced by commercial whalers in the last century. Whales were traditionally taken with harpoons and lances fashioned from stone, ivory, and bone. During the era of commercial whaling, Eskimos were often employed by vessels and shore-based stations to assist in taking whales. As a result, these people gained experience in the use of darting guns and shoulder guns and eventually acquired these weapons for personal use. After commercial whaling ceased, the Eskimos continued to use these weapons, which have not changed substantially in design since then.

Catch and Mortality Statistics

Data on the numbers of whales killed and recovered, known killed but lost, and struck and lost during each whaling

season from 1973 to 1976 have been recorded by NMFS observers (Table 12). Bowheads killed by the Soviets from 1972 to 1976 are presented in Table 13 to complete the known kill for subsistence during recent years. Bowheads are not hunted in the eastern Beaufort Sea by Canadian Eskimos (Sergeant and Hoek, 1974). In addition, an on-going literature search is being conducted by the author to obtain data on the historical subsistence kill by Eskimos to provide a comparison with the kill of recent years. These data are given in Table 14 along with recent data for numbers killed and recovered, the statistics judged to be most comparable to historical catch data.

Little information is available on the kill of bowheads by Soviet Eskimos. Zenkovich (1938) reports that Eskimos of the Chukchi Peninsula in particular hunt bowhead whales, though they catch no more than 10 tons each year. Geller (1957) claims that Soviet Eskimos catch mostly young whales weighing 4-5 tons. Tomilin (1957) writes "In the best years, up to 10 whales (including rorquals) are still" (exact year not known--assumed to be at least 1955, the date of the most recent literature citation used by him) "killed at the Chukchi Peninsula, mainly in the villages of Sireniki, Chaplino, Intuk, Naukan, and Uellen." In that area, the autumn rather than the Spring hunt is more rewarding, according to Tomilin. Zímushko (1969) states that bowhead are taken rarely by Eskimos of the Chukchi Peninsula. Mineev (pers. comm.), provided data showing that in recent years the Soviet Eskimo take has been about two whales per year (Table 13). Since 1964 the subsistence hunt has been conducted by USSR commercial-type whaling vessels that are employed primarily to obtain gray whales that are delivered to the villages on the basis of need.

Data on the numbers of whales killed and recovered, known killed but lost, and known struck and lost during each whaling season from 1973 to 1976 have been recorded to provide an evaluation of total mortality due to hunting. The number killed and recovered annually by Alaskan Eskimos since 1946 has varied from a low of one in 1959 to 48 in 1976 (Table 14). Prior to 1970, this annual take varied considerably but did not exceed 23 and averaged 10 bowhead whales. However, in the seven years since 1970, this annual take has exceeded 23 bowheads five times the averaged 29. A harvest of this size represents a sudden and significant increase in the annual take of these whales by Alaskan Eskimos.

Table 12.--Numbers of bowheads taken, known killed but lost, and known struck but lost for the whaling seasons 1973, 1974, 1975, and 1976

Season and location	Killed and recovered				Known killed but lost				Known struck but lost			
	73	74	75	76	73	74	75	76	73	74	75	76
SPRING												
St. Lawrence Is.	6	2	1	8	0	0	1	0	3	2	3	5
Kivalina	0	0	0	0	0	0	0	0	0	1	0	0
Point Hope	7	6	4	12	0	1	0	0	0	5	13	12
Wainwright	3	1	0	3	0	0	0	-	0	0	0	-
Barrow	15	6	10	13	0	1	1	7	7	19	10	18
TOTALS	31	15	15	36	0	2	2	7	10	27	26	35
AUTUMN												
Barrow	2	3	0	10	0	1	0	1	0	1	0	0
Nuiqsut	1	0	0	0	0	0	0	0	0	0	0	0
Kaktovik	3	2	0	2	0	0	0	0	0	0	0	0
TOTALS	6	5	0	12	0	1	0	1	0	1	0	0
GRAND TOTAL	37	20	15	48	0	3	2	8	10	28	26	35

Table 13.--Bowhead whales taken by USSR natives in recent years

Year	Chukchi Sea	Bering Sea	Total
1972	0	1	1
1973	0	2	2
1974	1	2	3
1975	2	2	4
1976	0	0	0

Source: Personal communication from Dr. V.N. Mineev.

Table 14 .-- Bowhead whales taken by Alaskan Eskimos and Shore-based Stations in the western Arctic Ocean.

Year	Barrow	Pt. Hope	Wainwright	Nuigsut	Icy Cape	Kaktovik	Gambell	Savoonga	Kivalina	Misc.	Total
1852	17										17
1853	7										7
1854-79											-
1880		5									5
1881	18										18
1882	1										1
1883	2										2
1884	10										10
1885	28	12									40
1886											-
1887	6										6
1888	2										2
1889	4										4
1890	1	1									2
1891	18										18
1892	8	0									8
1893											-
1894	10										10
1895	4										4
1896	6	33									39
1897	5										5
1898	42[1/]	1									43
1899											-
1900	19										19
1901		1									1
1902		2									2
1903	4	0									4
1904	2	0									2
1905	5										5
1906	1										1
1907	9	0									9
1908	23	13			10-12						46-48
1909	11	13			1						25
1910	2+										2
1911	1	3									4

Table 14 . (continued)

Year	Barrow	Pt. Hope	Wainwright	Nuigsut	Icy Cape	Kaktovik	Gambell	Savoonga	Kivalina	Misc.	Total
1912	2	1									3
1913	4	1									5
1914	1	2			1						4
1915		3									3
1916	5	7	1							1	14
1917		3			3					2	8
1918	1	7									8
1919	1	2									3
1920		3									3
1921		2									2
1922	1	13	3								17
1923										2	2
1924		16								9	25
1925	19	10	2								31
1926	4	13									17
1927	2	3									5
1928	11										11
1929	15										15
1930	7										7
1931	11	1									12
1932	7										7
1933	5										5
1934	4										4
1935	6										6
1936	4	4									8
1937	9										9
1938	4										4
1939	6										6
1940	0	5									5
1941	2	8	1								11
1942	10		1								11
1943	6										6
1944	0		2								2
1945	3	3									6
1946	9	2									11

Table 14. (continued)

Year	Barrow	Pt. Hope	Wainwright	Nuigsut	Icy Cape	Kaktovik	Gambell	Savoonga	Kivalina	Misc.	Total
1947	4	6									10
1948	5	0									5
1949	0	4	1								5
1950	4	2	2							1 (Cape Lisburne)	9
1951	9	4									13
1952	0	2+									2
1953	17	4					2				23
1954	1	3									4
1955	19	1	1				2				23
1956	2	2					1				5
1957	0	3					0				3
1958	0	2					0				2
1959	0	1									1
1960	15	4	0								19
1961	6	2	1				1				10
1962	5	6	1								12
1963	5	3	2								10
1964	11	1	1			2			1		16
1965	4	2	0								6
1966	7	5	1								13
1967	3	1	0								4
1968	10	3	2				1				16
1969	11	3	3							1 (Wales)	18
1970	15	8	0						1		24
1971	13	6	2				1		1	1 (Wales)	24
1972	19	14	2				2		1		38
1973	17	7	3	1		3	2	4			37
1974	9	6	1			2	2		0		20
1975	10	4	0				1		0		15
1976	23	12	3			2	1	7	0	0 (Wales)	48

1/. Combined catch of Eskimos and two vessels.

The Eskimos attempt to take only small whales because of their superior palatability. From 1973 to 1976 measurements or estimates of body length were obtained for 45 males, 34 females, and 13 whales of unknown sex, a total of 92 whales (Tables 1, 11, and 15-17). Of these animals, 20 ranged in length from 460 to 796 cm (15 feet, 1 inch to 26 feet, 1 inch). Durham[5], believes that those individuals 670 to 792 cm (22 to 26 feet) in length are yearlings, perhaps 12 months of age. Rice and Wolman (1971) indicate that after the first year of growth, the body length of immature gray whales increases about 10 percent yearly. Assuming a similar growth rate for bowheads, immature individuals (less than 4 years of age according to Durham[5], might range from 810 to 975 cm (26.5 to 32 feet) in body length. The Eskimos captured 53 individuals less than 975 cm (32 feet) in length, therefore, 58 percent of all whales taken possibly were 3 years old or less when killed. Thus research indicates that a majority of the whales harvested by the Eskimos are small, a finding also noted by Bee and Hall (1956), Geller (1957), Maher and Wilimovsky (1963), and Durham[5].

Of the 120 whales killed and recovered by Eskimos from 1973 through 1976, sex was determined for 81 (Table 18). Of that number, 47 (58 percent) were males and 34 (42 percent) were females. The Eskimos may take smaller animals, not only because they prefer them over larger (and older) bowheads for food, but because young individuals predominate among whales migrating north early in the season. The large whales, including females with calves, appear later when the ice conditions generally become unsafe for the whalers. Such temporal segregation would also account for the greater proportion of males in the catch.

An example of inadvertant selection by sex may have occurred during the autumn hunt of 1976 at Barrow where unusually successful whalers caught a total of ten large bowheads. Since seven of the ten whales were males, a segration process may be occurring that might result from males leaving sooner than females, i.e., a temporal segregation by sex and reproductive state as noted for bowheads by Frazer (1976), Tomilin (1957), and Vinogradov (1949), for gray whales by Rice and Wolman (1971), and for humpbacks by Dawbin (1966).

Whales taken from 1973 through 1976 are presented by date, in Tables 19 and 20. The earliest date on which a whale was taken during this period was 21 April, and the latest during the spring season was 6 June. For the total of 80 whales for which the date is known, 39 animals (56 percent) were killed 1-15 May, which may indicate that this period is normally the peak of the spring migration. According to Maher and Wilimovsky (1963), 72 percent of the whales taken at Barrow

Table 15.--Biological features of bowhead whales taken during the 1973 whaling season.

Area	Date	Body length (centimeters)	Sex	Remarks
		SPRING		
Barrow	7 May	823	M	
	7 May	670	M	
	7 May	915	F	
	12 May	915	F	
	12 May	910	M	
	13 May	820	M	
	23 May	855	F	
	24 May	884	F	
	24 May	610	M	
	24 May	--	M	
	25 May	975	F	
	27 May	823	F	
	28 May	762	M	
	6 June	1525	F	
	6 June	460	M	
Wainwright	19 May	1036	F	
	20 May	825	F	
	23 May	--	-	
Point Hope	5 May	--	-	
	5 May	--	-	
	17 May	--	-	
	18 May	--	-	
	19 May	--	-	
	23 May	--	-	
	25 May	--	-	
St. Lawrence Island	-	--	-	
	-	--	-	
	-	--	-	
	-	--	-	
	-	--	-	
	-	--	-	
		AUTUMN		
Nuiqsut	-	--	-	
Kaktovik	-	--	-	
	-	--	-	
	-	--	-	
Barrow	-	--	-	
	-	--	-	

Table 16.--Biological features of bowhead whales taken during the 1974 whaling season.

Area	Date	Body length (centimeters)	Sex	Remarks
	SPRING			
Point Hope	21 April	1219	-	
	21 April	914	-	
	20 April	813	M	
	2 May	869	M	
	11 May	757	F	
	23 May	1524	M	
	25 May	1550	M	
St. Lawrence Island				
Gambell	29 April - 1 May	1219	-	
	2 May	1219	-	
Wainwright	31 May	--	-	
Barrow	30 April	975	-	
	4 May	671	M	
	12 May	813	M	
	16 May	1135	F	Ingutuvak
	29 May	1385	M	Stinker
	29 May	--	-	Not recovered
	29 May	724	F	Ingutuk
	AUTUMN			
Barrow	29 Sept.	975	M	
	29 Sept.	--	M	Lost in heavy seas
	3 Oct.	1067	M	
	8 Oct.	823	F	
Kaktovik	10 Sept.	--	-	
	before 24 Sept.	--	-	

Table 17.--Biological features of bowhead whales taken during the 1975 whaling seasons.

Area	Date	Length (in centimeters)	Sex	Remarks
		SPRING		
St. Lawrence Island				
Gambell	23 April	--	-	Sank, line broke
	7 May	1280	M	
Point Hope	24 April	1097 1/	-	Ingutuvak
	26 April	610 1/	-	
	10 May	846	F	Ingutuk
	15 May	1158 1/	M	
Barrow	5 May	795	F	
	9 May	691	M	
	13 May	927	F	
	14 May	800 1/	-	
	15 May	854	M	
	15 May	--	-	Sank
	16 May	1620	F	Lactating
	20 May	784	F	Ingutuk
	21 May	1111	F	
	23 May	715	-	
	31 May	1402	M	Stinker
		AUTUMN		
Barrow	None			
Nuiqsut	None			
Kaktovik	None			

1/ Length estimated by natives.

Table 18.--Number of male and female bowhead whales taken by Eskimos in Alaska, 1973 - 1976, for which sex is known

Year	Males	Females	Totals
1973	8	9	17
1974	10	4	14
1975	5	6	11
1976	24	15	39
Totals	47	34	81
Percent	.58	.42	

Table 19.--Dates bowhead whales taken by Eskimos during the spring seasons 1973 - 1976.

Date	Number	Date	Number
21 April	2	21 May	1
22	0	22	0
23	1	23	4
24	1	24	3
25	0	25	1
26	1	26	1
27	0	27	1
28	0	28	1
29	0	29	2
30	2	30	0
		31	1
1 May	1	1 June	0
2	5	2	0
3	3	3	0
4	1	4	0
5	2	5	0
6	4	6	2
7	4		
8	0		
9	3		
10	1		
11	2		
12	4		
13	2		
14	3		
15	4		
16	2		
17	1		
18	0		
19	2		
20	2		

Table 20.--Dates bowhead whales taken by Eskimos during the Autumn seasons 1973 - 1976.

Date	Number	Date	Number
28 August	1	21 September	0
29	0	22	0
30	1	23	0
31	0	24	0
		25	0
1 September	0	26	0
2	0	27	1
3	3	28	0
4	0	29	0
5	0	30	0
6	0		
7	0	1 October	0
8	0	2	0
9	0	3	0
10	1	4	0
11	0	5	0
12	0	6	0
13	0	7	1
14	0		
15	0		
16	0		
17	0		
18	0		
19	0		
20	4		

from 1954 to 1960 were killed 4-18 May; then concluded that the migration peak may occur within this period. During the autumn hunt, the earliest date on which a whale was killed from 1973 to 1976 was 28 August, and the latest 7 October. Of only 23 whales taken in autumn from 1973 to 1976, 12 were harvested in 1976. Consequently, it is difficult to conclude much about timing of the autumn migration. However, a majority of the whales were taken by 20 September, possibly indicating that the peak of the autumn migration past Barrow occurs about mid-September.

Killed but Lost

Bowhead whales known to have been killed and lost must be added to those killed and recovered to derive the total annual known kill. Most of the information on whales killed and lost is, at best, sketchy and unverified because it is based upon statements made by whalers, or rarely from observations of investigators. Data obtained by NMFS observers shows that the number killed and lost varied from none in 1973 to eight in 1976 (Table 12).

The only information available on whales found dead near the whaling villages is that obtained in 1976. Five dead bowhead whales were seen in the ice in mid-May near Point Hope (E. Valentine, pers. comm.). A first assumption may be that these whales were wounded by whalers from that village and that they died nearby from their injuries. Tomilin (1957) reported, however, that some Soviet Eskimos have in the past sought the carcasses of bowheads that occasionally become trapped in shifting ice and evidently perish of natural causes. Although he admits that this phenomenon is rare (the bowhead is well adapted to and therefore capable of surviving in the ice), it occurs frequently enough to justify its consideration as a hunting technique. Although insufficient information is available for the evaluation of this occurrence near Point Hope, it should not be assumed that all five whales died from injuries inflicted by Point Hope whalers. The results of OCSEAP aerial surveys list one dead whale in the ice far offshore from Barrow 24 May, and another frozen in the ice north of Barrow that was being fed upon by a large number of polar bears. Identification of these carcasses was not verified but, assuming that they were all bowheads, the kill in 1976 includes 48 recovered and 15 killed but lost, a total of 63 whales. This number of bowheads is the largest known to have been killed by the Eskimos in a single year.

Struck and Lost

The evaluation of data on wounded and lost whales is difficult because it is not known how many of these animals may have died. Various estimates of the number of whales struck and lost compared to the number killed and recovered have been made. Johnson et al (1966) wrote that even when struck the whales are only secured about 25 percent of the time. Durham (1974) states that only about one in four or five whales struck is recovered. However, statistics gathered by Foote (Pers. comm.) from various sources show that 37 bowheads were struck and lost compared to 36 killed and recovered at Point Hope (Table 21), indicating that 50 percent of all whales struck were lost. Scott (1951) reported that up to 50 percent of all whales hit are not recovered, primarily because of poor equipment. NMFS observations since 1973 yield similar findings. A total of 112 whales (48 percent) was known to have been lost (99 struck and lost and 13 killed and lost) compared to 120 that were killed and recovered. It is difficult to obtain exact figures on this subject because most are obtained from statements made by the whalers, which may account for the wide range of figures reported for whales that have been struck and lost.

Our finding that 50 percent of all whales struck are lost by Eskimo whalers (admittedly a minimum figure) may approximate reality. Early commercial whalers perfected their technique to where they recovered an average 67 percent or greater of all whales struck, according to Bodfish (1936), who on one occasion harpooned 16 whales, losing only four. Scammon (1874) stated that only 20 percent of all whales struck are lost. Although it is doubtful that the rate at which the Eskimos strike and lose whales approaches that of early professional whalers, a 50 percent loss rate may be assumed to be reasonable because of the subsistence value and prestige gained by taking a whale.

Fragments of bombs or harpoons have not been found in whales taken by the Eskimos since the NMFS has been monitoring the harvest, but Durham[7/] found an old bullet in the blubber of one animal. A few whalers have stated that they occasionally find an old harpoon or fragments of harpoons or bombs in whales that they have taken. The fact that harpoons may remain embedded in whales for many years has been established in at least four instances (Clark, 1887; Dall, 1899; and Colby, 1936). The discovery of old whaling equipment in bowheads provides evidence that bowheads can survive abortive hunting attempts.

7/ Durham, Floyd E. 1973. Census and Spring Migration Studies on the Bowhead Whale in the Western Arctic in 1973. Univ. So. Calif. Los Angeles, contract No. 03-3-208-200 with NMFS, Seattle, Wash., Unpublished report, 15 November 1973.

Table 21.--Data collected by Foote[1/] on numbers of bowhead whal. that were struck and lost compared to those killed and recovered for various years from 1915 to 1962, at Point Hope, Alaska.

Date	Killed and Recovered	Struck and lost
1915	3	3
1916	7	1
1917	3	2
1940	5	8
1951	4	8-10[2/]
1956	2	3
1960	4	10
1961	2	2
1962	6	1
Totals	36	39

1/ Personal communication, D.C. Foote to D.W. Rice, 2 November 1964.

2/ The larger number (10) was used to obtain total of 39.

Strandings

Strandings of bowhead whales on arctic shores apparently are infrequent. Durham[7] reported the only stranding that he knew about occurred in September, 1964, near Barter Island. Sergeant and Hoek (1974) state that strandings rarely occur along Canadian shores and that those they know of are the cumulative results of many years.

Biological samples

Material may be collected freely by anyone from the remains of whales abandoned by the Eskimos, but material from a newly taken whale may be collected only with the permission of the captain of the crew that took the animal. An ancient custom of returning the skull to the sea after removal of desirable portions from the head is observed by many Eskimos at Barrow and by all at Point Hope. The whalers must butcher the whales as rapidly as possible to avoid loss of the carcass due to shifting ice. For this reason they do not tolerate interference with the butchering process, which may take 3 to 30 or more hours. Thus, it is seldom possible to obtain all of the desired measurements and samples from each whale, which is usually available for this purpose only on an opportunistic basis. Measurements of the morphological features of bowhead whales taken by the Eskimos from 1973 to 1976 are presented in the appendix.

Some biological samples have been obtained from most whales taken by the Eskimos since 1973. Every effort has been made to obtain ovaries, testes, and baleen for age and reproduction studies. Other samples frequently collected included tissues from the skin, blubber, muscles, heart, lungs, liver, and intestines. Various organs and bones have also been collected, including eyes, small ear bones, and the entire reproductive tract of one young female. Although Durham[57] states that the wax ear plugs cannot be used to estimate the age of bowheads, several ear plugs were collected but a satisfactory method for keeping them intact has not been discovered. A bowhead fetus 131 cm (4 feet, 4.5 inches) in length was removed from a 1730 cm (56 feet, 9 inch) female taken during the autumn of 1976, and sent to the U.S. National Museum at Washington, D.C. This fetus is the only one found since the NMFS began to monitor the Eskimo harvest of bowhead whales in 1973.

Bowheads do not appear to feed during the spring migration and few stomachs containing food have been found at that time of year. The only stomach content noted during our study was a black liquid. During his 13-year study Durham[57] found some food in seven of ten stomachs examined during the spring,

which he identified as being green matter like bile or digested phytoplankton, copepods, euphausiids, mysids, amphipods, gammarids, and two 12.7 cm (5 inch) long cottids. Johnson et al. (1966) examined three whales taken during the spring. The stomachs of a young male and a lactating female were empty and the stomach of a young female contained a few items of food (Table 22). Scoresby (1820) reported finding only squillae or shrimps in the mouth of one individual and in the few stomachs he was able to examine. Mitchell (1974a) states that bowheads feed on mysids and various other small to medium sized zooplankton and notes various sources that indicate it is sometimes a bottom-feeder and eats amphipods.

Some food has been found in the stomachs of whales taken during the autumn hunt. The stomachs of two whales taken during the autumn at Barrow in 1976 contained food (Table 22). Durham5/ examined the stomachs of 7 whales, of which six contained mysids, gammarids, green matter, amphipods, some bone fragments of small fish, mud dwelling tunicates, vegetation silt, and a few small pebbles. Durham5/ believed that bowheads feed sporadically and lightly during their migrations in spring and autumn, and Johnson, et al. (1966) concluded that bowheads do little feeding while migrating.

As mentioned above, the bowhead feeds by straining marine organisms through its many baleen plates. Scoresby (1820) reported that "each side of bone consists of upwards of 300; in a small whale the number was 316 or 320." Eschricht and Reinhardt (1866) reported counts of 308 distinct blades for a newborn and 310 for an individual 670 cm (22 feet) in length. Scammon (1874) wrote that 330 on each side was a fair average, and 370 was the highest count obtained. Cook (1926) stated that the total number of baleen plates varies from 550 to 650. These figures suggest that the total number of baleen plates in the bowhead can vary considerably. We obtained counts of baleen plates on one side of the mouth for 12 females, 10 males, and one animal of unknown sex. For females the count varied from 274 to 329 (average - 302). For males the number ranged from 237 to 346 (average - 305). Our data indicates that the females have a smaller range (274 to 329), with a higher minimum (274) and a lower maximum (329) than do the males with a greater range (237 to 346) and a lower minimum (237) and higher maximum (346). Our data sample is relatively small, however; future counts may provide more insight into the significance of baleen counts.

NMFS observers attempt to obtain one piece of the longest baleen from each whale taken by the Eskimos for determining age. Occasionally, when some or all of the baleen had been removed from the butchering site, the homes of the whalers were subsequently visited to obtain measurements and samples of what we were informed was the longest baleen from specific whales.

Table 22.--Stomach contents of bowhead whales.

Specimen number	Date	Species	Volume (ml)	Comments
76B6F[1/]	10 Sept. 1976	Thysanoessa raschii	17.0	Contents badly digested and broken up.
		Rozinante fragilis	0.1	
		Parathemisto libellula	0.4	
		Small pebble	<0.1	
76B7F[1/]	20 Sept. 1976	Thysanoessa raschii	28.6	All specimens for which species could be determined were of this species.
		Gammarus zaddachi	0.5	3 individuals
		Acanthostepheia behringiensis	1.8	10 individuals
		Monoculoides zernovi	0.6	8 individuals
		Rozinante fragilis	0.5	6 individuals
		Parathemisto libellula	1.0	10 individuals
		Shrimp	<0.1	partial carapace only, perhaps family Hippolytidae
M1527[2/]	13 May 1961	Polychaeta		Stomach nearly empty, fragmentary remains only.
		Reptantia		
		Gastropods		
		Crustacea		
		Echinoidea		
		Sand and gravel		

1/ Identified by L. Lowry, Alaska Department of Fish and Game.
2/ Johnson, et al., 1966.

All whales examined were inspected for parasites. Ectoparasites (Cyamid sp.) were collected from three whales, and were reported for but not collected from two other animals. No endoparasites were observed. Our observations confirm previous reports, one in 1874 by Scammon, that bowheads are remarkably free from parasites.

Because NMFS observers cannot always be present before the whales are cut up, body length can be obtained for only a few of the animals harvested. As a result, the relationship of certain other body measurements (i.e., fluke width at insertion, juncture of fluke and body, and length of the mandible) to total length has been examined to determine if they can be used to estimate the total length of cut up whales (Tables 23 and 24). The relationship of total fluke span to body length has also been examined as an aid in determining the length of whales taken by early whalers, who measured and reported fluke width, especially those for extraordinarily large whales (Table 24). Such information may make possible conversion of all early measurements of bowheads to a standard length, i.e., total length from the tip of the rostrum to the notch of the flukes, in a straight line parallel to the body axis.

Cooperative research on biological specimen material from bowhead whales is being conducted with several interested scientists. Included are studies of the integument, biology and morphology, genetic karyotyping, sight, hearing, parasites, nerves innervating the body skin, chemical pollution, physiology involved with diving, and food. A study on hearing has been partially completed and reported on by Fleischer (1976), and food from the stomachs of two whales has been identified (L. Lowry, pers. comm.).

Table 23.--Comparison of measurements of bowhead whale mandible to total length of whale (in centimeters).

Specimen number	Male: Total length	Male: Length of mandible	Male: Percent of total length	Female: Total length	Female: Length of mandible	Female: Percent of total length
4472	610	250	.4098	--	--	--
4462	670	287	.4284	--	--	--
74B6	671 1/	217	.3234	--	--	--
75B2	691	218	.3155	--	--	--
76B1	750	315	.4200	--	--	--
76B5	--	--	--	750	292	.3893
74H3	--	--	--	757	230	.3038
4476	762	272	.3570	--	--	--
76H12	762	250	.3281	--	--	--
75B7	--	--	--	784	243	.3100
75B1	--	--	--	795	295	.3711
76H11	--	--	--	808	262	.3243
74H1	813	254	.3124	--	--	--
74H2	813	264	.3247	--	--	--
4461	823	274	.3329	--	--	--
76H9	--	--	--	825	267	.3236
75H3	--	--	--	846	255	.3014
76H8	--	--	--	848	285	.3361
75B5	854	271	.3173	--	--	--
76B12	--	--	--	854	245	.2869
74H2	869	283	.3257	--	--	--
4471	--	--	--	884	267	.3020
75B3	--	--	--	927	333	.3592
4474	--	--	--	975	285	.2923
76B7	980	328	.3347	--	--	--
75B8	--	--	--	1111	421	.4164
76H2	1021	350	.3428	--	--	--
76B10	1100	380	.3454	--	--	--
76H4	1120	384	.3429	--	--	--
74B3	--	--	--	1135	263	.2317
76B2	1144	419	.3663	--	--	--
76B6	1235	437	.3538	--	--	--
76H3	--	--	--	1321	445	.3369
75B10	1402	464	.3510	--	--	--
76H6	1468	430	.2929	--	--	--
76B6F	--	--	--	1600	580	.3625
75B6	--	--	--	1620	562	.3469
Average			.3452			.3291
Sex unknown						
75B9	715	226	.3161			
76B3	796	275	.3455			
75B4	927	276	.2977			
74B1	975	314	.3220			
Average			.3203			

1/ Length estimated by natives.

Table 24.--Percentage of total length of whale represented by the span of the flukes and fluke width at insertion (measurements in centimeters).

Specimen number	Length	Fluke span: Female	Percent	Male	Percent	Fluke width at insertion: Female	Percent	Male	Percent
4478	460	--	--	137	.2978	--	--	38	.0826
4472	610	--	--	250	.4098	--	--	--	--
76B11	685	280	.4088	--	--	72	.1052	--	--
75B2	691	--	--	220	.3184	--	--	60	.0868
74H3	757	--	--	--	--	70	.0925	--	--
76H12	762	--	--	--	--	--	--	75	.0984
75B7	784	228	.2908	--	--	58	.0740	--	--
75B1	795	263	.3308	--	--	62	.0800	--	--
4461	823	--	--	245	.2977	--	--	--	--
4475	825	254	.3079	--	--	64	.0776	--	--
75B5	854	--	--	254	.2974	--	--	68	.0796
76B12	854	245	.2869	--	--	60	.0703	--	--
4470	855	264	.3088	--	--	--	--	--	--
74H2	869	--	--	--	--	--	--	70	.0806
4471	884	254	.2873	--	--	66	.0747	--	--
4466	910	--	--	307	.3374	--	--	65	.0714
4474	975	280	.2872	--	--	72	.0738	--	--
76B7	980	--	--	289	.2949	--	--	74	.0755
76H2	1021	--	--	--	--	--	--	83	.0813
76B9	1070	--	--	--	--	--	--	84	.0785
76B10	1100	--	--	371	.3373	--	--	90	.0818
75B8	1111	390	.3510	--	--	84	.0831	--	--
74B3	1135	305	.2687	--	--	70	.0617	--	--
76B2	1144	--	--	323	.2824	--	--	74	.0647
75H4	1158	--	--	--	--	--	--	73	.0630
76B13	1158	318	.2746	--	--	86	.0743	--	--
76B6	1235	--	--	362	.2931	--	--	82	.0664
76B8	1370	--	--	435	.3175	--	--	100	.0730
75B10	1402	--	--	498	.3552	--	--	123	.0878
76H6	1468	--	--	--	--	--	--	122	.0831
76H9F	1525	--	--	--	--	--	--	123	.0807
76B6F	1600	575	.3594	--	--	140	.0875	--	--
75B6	1620	551	.3401	--	--	139	.0828	--	--
Average			.3156		.3199		.0798		.0785
Sex Unknown									
76B3	796					63	.0792		
76B4	1136	366	.3222			86	.0757		
				Average			.0774		

REPRODUCTION AND GROWTH

Little is known about the reproduction and growth of bowhead whales. The harsh habitat occupied by this species has not been conducive to studies of their behavior and other natural history aspects. What little data that have been recorded in the literature were obtained by a few of the early whalers. Scoresby (1820, 1823) has given some accounts, as have Eschricht and Reinhardt (1866), and Scammon (1874).

In recent years a major contribution to the biology of bowhead whales was made by Durham[5/] in his study from 1961 to 1973. The NMFS has conducted research on these whales in 1961 and 1962 and from 1973 to the present. Because so little information on the biology of these animals is available, we have combined the results of our research with information from the literature into a summary of available data on the reproduction and growth of bowhead whales.

The mating season for bowheads is not well defined. Scoresby (1820) reported that the whales had often been observed to mate during the latter part of summer. According to Eschricht and Reinhardt (1866), mating occurred in Greenland waters during January and February. Foote[4/] observed behavior among the adults in May which suggested that copulation occurs during the spring migration. One instance of copulation apparently in progress within a pod of six adults was photographed during an OCSEAP aerial survey on 8 May 1976, near Point Barrow (H. Braham, pers. comm.). More observations are needed, however, before the range in time over which copulation occurs can be defined, but it appears to occur during the spring migration and in summer.

The gestation and calving periods, like the mating period, also are not well defined for this species. Information concerning fetuses and newborn calves of bowheads has been rarely recorded in the literature. Scoresby (1820) believed that gestation lasted 9-10 months and presumed that birth occurred in February or March, although he reported that a young calf with the umbilical cord still attached was taken by a Hull whaler in the latter part of April, 1811. Eschricht and Reinhardt (1866) disagreed with Scoresby, stating that gestation is 13-14 months and that birth occurs between late March and early May. They agreed that the female produces only one young, and Scoresby stated that two calves with a female were rarely seen. Scammon (1874) concluded that the calves apparently are born along the way during the spring migration. Gray (1886) did not believe that the young were born at a definite time, stating he had seen females with very young calves early in May and late in July. Maher and

Wilimovsky (1963) state that adult females with calves are seen from about mid-May to mid-June at Barrow; in 1955 the first female with a calf was seen on 15 May.

Durham[5/] infers from indirect evidence that breeding and calving occur in early April, just before the whales reach Point Hope during their migration northward in the spring. He states that pregnant females taken in autumn by the Cape Smythe Whaling Company at Barrow contained fetuses that were 183 to 244 cm (6 to 8 ft) in length. Durham concludes from the available evidence that gestation is 12 months and, because pregnant cows taken at Barrow were not lactating, that the female normally bears a calf every second year, or less often.

Observations made by NMFS observers since 1973 indicate that cows with calves pass by Point Hope and Barrow in late May. These sightings and those obtained from the literature are contained in Table 25. Data on embryonic and newborn lengths are presented in Figure 2. The available information suggests that most mating and calving probably occurs during April and May, and that the gestation period is about 12 months. Each activity can be expected to occur over some range in time, and therefore to overlap.

Length of the calves at birth is reported by Eschricht and Reinhardt (1866) to be from 396 to 427 cm (13 to 14 feet), Bodfish (1936) states it is 305 to 366 cm (10 to 12 feet), and Scoresby (1820) places it at 305 to 427 cm (10 to 14 feet). Bodfish (1936) reported seeing many calves, the smallest from 305 to 366 cm (10 to 12 feet) in length, but that a Captain Tilton, whom he had sailed with, told him of once finding a cow with a newborn calf that was only 152 or 183 cm (five or six feet) long. These lengths agree with that of a recently born calf taken at Barrow on 20 May 1954, which was estimated by the Eskimos to be 305 to 366 cm (10 to 12 feet) in length and one to two weeks old.

We do not know how long the lactation period is nor how long calves remain with their mothers. Scoresby (1823) observed sucklings in the waters of Spitzbergen and Greenland from April through July. Scammon (1874) wrote, "It has been a mystery among the most experienced whalemen, as to where the bowheads resorted to bring forth their young, or where the young remained until grown to a considerable degree of maturity; but within a few years, whales have been seen around Point Barrow with young calves...", and he speculated "that that area of the Beaufort Sea from Point Barrow to Banks Island doubtless affords ample herding and breeding places for the whales indigenous to the region." Gray (1886) states "There is a great deal still to be

Table 25.--Dates female bowhead whales and calves have been observed.

Date	Remarks	Source
18 March 1807	Female with newborn, newborn killed	Eschricht & Reinhardt (1866)
14 April 1961	Female with very small calf sighted	Foote[4/]
20 April 1962	Female with yearling calf sighted	Foote[4/]
April 1811	Newborn, umbilical attached	Scoresby (1820)
29 April 1956	Newborn, killed	Maher & Wilimovsky (1963)
6 May	Newborn 396 cm (13 ft) umbilical attached	Eschricht & Reinhardt (1866)
May	Newborn	Durham[5/]
13 May 1961	Female with calf sighted	Foote[4/]
13 May 1961	Female with calf sighted	Foote[4/]
13 May 1962	Small calf sighted	Foote[4/]
15 May 1962	Female with calf sighted	Foote[4/]
16 May 1975	Lactating female 1620 cm killed	Marquette (1976)
16 May 1976	Female and calf sighted	Fiscus, Braham and Marquette[1/]
20 May 1954	Newborn 305-366 cm (10-12 ft) killed, estimated 1-2 weeks old	Maher & Wilimovsky, (1963)
22 May 1976	Female and calf sighted	Fiscus, Braham, and Marquette[1/]
24 May 1961	Calf killed, sank	Foote[4/]
24 May 1961	Lactating female killed, 1417 cm (46 ft 6 in)	Johnson, et al. (1966)
27 May	Female 1371 cm (45 ft) and calf killed	Durham[5/]
28 May	Female with calf killed	Bodfish (1936)
28 May 1971	Newborn 447 cm (14 ft 8 in) killed	NARL Staff (1972)
28 May 1971	Female 1560 cm (51 ft 2 in) killed, mother of newborn killed	NARL Staff (1972)
28 May 1975	Female and calf sighted	Marquette (1976)
3 June 1971	Small calf killed	Pedersen, pers comm.
6 June 1973	Newborn, 460 cm (15 ft 1 in) killed	Durham[8/]
June 1811	Nursing calf harpooned	Scoresby (1820)
June 1851	Calf sighted	Allen (1973)
15 July 1821	Nursing calf 579 cm (19 ft) killed	Scoresby (1823)
30 Sept. 1736	Newborn, 549 cm (18 ft) killed prior to this date, preserved and arrived in port on this date.	Slijper (1962)
2 Oct	Calf 549 cm (18 ft), estimate of length from skull measurements	Durham[8/]

found out as to where the old cows disappear to after calving; for after 40 years whaling experience in the Greenland Sea I have not seen more than a dozen accompanied by calves." Evidence that cows with nursing calves can be very secretive and successfully evade observation is demonstrated by the gray whale (Rice and Wolman, 1971). Slijper (1962) recorded a 12-month lactation period. Tomilin (1957) states "The functional leap in baleen growth, when the calf begins to consume adult food, usually takes place upon attaining a length of 7 to 8.5 m (23 to 27 feet, 11 inches) in Greenland right whales. This size marks the end of lactation." Durham[5/] considers whales within this length range to be yearlings.

Allen (1973) writes that a Soviet officer told him that he had seen the beach covered with dead calves in the winter, about the entrance of the Bay of Petropavlovski (on Kamchatka Peninsula), but he does not say whether the officer advanced a reason for their deaths. The dead calves may have been associated with the birth process as described for the gray whale by Gilmore (1958), or they may have been a pod of yearlings described as calves that were trapped by the ice and suffocated.

Adult females accompanied by calves have been observed from 18 March to 2 October (Table 25). Early observations made by commercial whalers were limited to time periods when they could safely navigate their vessels in the ice-filled waters of the arctic. Sightings reported in recent years have been made primarily from the edge of the lead during the spring whaling season, and from small boats during the autumn hunt by the whalers of Barrow. A small calf taken at Barrow 2 October was believed by Durham[8/] to have been weaned. From measurements of the skull he estimated the length of the calf at 549 cm (18 feet) and its age at about 6 months. Since lactating females have not been taken by whalers in the autumn it may indicate early weaning, perhaps at age 5 or 6 months.

Sexual maturity in bowhead whales is reached at a length of 1158 cm (38 feet) for males and at 1220 cm (40 feet) for females at age 4 years according to Durham[5/]. He recorded a 1371 cm (45 foot) long female with a calf taken on 27 May, the remains of a pregnant female estimated to be 1310 cm (43 feet) long with a 152 cm (5 foot) long fetus taken near Barrow on 10 May, and a pregnant female 1570 cm (51 feet, 6 inches) in length containing a 25 cm (10 inch) embryo taken on 2 June near Barrow. A newborn calf, a fetus, and their mother were taken and measured during the present study. A female 1525 cm (50 feet) and its 460 cm (15 feet, 1 inch) newborn calf were taken on 6 June 1973 at Barrow. In the autumn of 1976, a 131 cm (4 feet, 3.5 inch) fetus was removed from a female that was 1730 cm (56 feet, 6 inches) long as measured by the whaling captain from Barrow

that killed it. Because most of the whales taken by the Eskimos are immature, data obtained during the present NMFS study is not sufficient to make conclusions regarding sexual maturity.

Some data were obtained indicating the approximate length at which bowheads attain physical maturity. Examination of the degree of fusion of the vertebral epiphyses with the centra showed that for one male 1120 cm (36 feet, 9 inches) in length, completed; for a male 1158 cm (38 feet) in length, fusion was about 25 percent completed; but for a male 1468 cm (48 feet, 2 inches) in length, fusion was complete for a male 1402 cm (46 feet) in length, but incomplete in a male 1490 cm (48 feet, 10.5 inches) in length. Durham[5/] found that a 1676 cm (55 foot) female he had examined had not yet matured physically. Attainment of physical maturity for males is therefore apparently reached between 1402 cm (46 feet) and 1468 cm (48 feet, 2 inches), or possibly 1524 cm (50 feet) in length. Females apparently become physically mature at a length slightly greater than the males. Some variation can be expected in the length at which individuals attain physical maturity, as shown by the 1676 cm (55 foot) long but physically immature female reported by Durham, a finding also reported by Eschricht and Reinhardt (1866).

Baleen has been examined by many investigators in efforts to determine the ages of whales. Although some disagreement exists, it is thought that the growth ridges on baleen plates represent true growth rings or marks (Scoresby, 1820; Eschricht and Reinhardt, 1866; Wheeler, 1930; Ruud, 1940, 1945; Tomilin, 1945; Ruud, Jonsgard, and Ottestad, 1950; Nishiwaki, 1950, 1951; Robins, 1960; and Utrecht and Utrecht-Cock, 1968). Lengths of the longest plates from several bowhead whales are compared to their body lengths in Table 26, and except for a few deviations, length of the baleen generally increases with length and, possibly, age of the animal. Disparities may result from erroneous measurements or in recording of data, or because some baleen was incorrectly identified for our observers as being the longest plates from specific whales. All baleen samples will be examined to determine whether the ages of whales can be told using this technique, and the results will be reported in the future.

ABUNDANCE

Estimates of Original Population

The size of the original population of bowhead whales in the western Arctic is not known. Determination of the historical annual catch of bowheads can, however, provide a basis for estimating the size of the former population before whaling

Table 26. Total number of baleen on one side of mouth and length of longest baleen compared to total length of the whale.

Sex	Specimen number	Length (cm)	Number baleen	Longest baleen (cm)
FEMALE	74B5	724	---	60
	76B5	750	281	137
	74H3	757	280	66
	75B7	784	274	70
	76H11	808	304	123
	4475	825	---	69
	75H3	846	275	90
	76H5	853	320	--
	76B12	854	303	79
	76H10	889	307	145
	4464	915	---	154
	4463	915	---	160
	75B3	927	323	155
	4474	975	---	140
	75B8	1111	324	221
	74B3	1135	298	57
	76H3	1321	329	212
	76B7F	1430	---	280
	75B6	1620	---	313
		Average	302	
MALE	4472	610	---	69
	4462	670	---	156
	75B2	691	---	45
	4476	762	---	127
	76H12	762	294	--
	74H1	813	--	85
	74B2	813	321	97
	4461	823	---	155
	75B5	854	335	126
	74H2	869	288	118
	4466	910	---	183
	76H2	1021	346	138
	76B10	1100	342	--
	76H4	1120	285	200
	76B2	1144	315	226
	76B6	1235	237	--
	76B10F	1320	---	242
	75B10	1402	---	287
	76B8F	1408	---	230
	76H6	1468	283	256
	76B9F	1525	---	245
	76B2F	1630	---	290
		Average	305	
UNKNOWN	76B3	796	270	133
	74B1	975	---	129
	75H1	1097	---	95

seriously depleted the stock, and aid in determining an acceptable annual yield for the subsistence hunt conducted by the Eskimos. Knowledge of catch data for the shore-based aboriginal hunt and the early pelagic fishery by whaling vessels is needed to provide a basis for estimating the size of the original population of bowhead whales.

Size of the original population of bowhead whales in the western Arctic can only be estimated crudely. The commercial catch in 1880, 1885, and 1886 was 265, 220, and 153 whales (Clark, 1887), for an average harvest of about 200 animals a year. Utilizing information on annual average whalebone production, Rice[3/] (1974) estimated the population as around 4,000 or 5,000 during the period 1868-1884.

Historical Catch of Bowhead Whales

Little is known about the historical aboriginal harvest of bowhead whales because the Eskimos normally do not keep records of their whaling activities. Data on annual catches in the past can only be obtained, therefore, from the literature and by talking with individuals possessing such information. Narrative reports by residents of Point Hope relate the taking of 15 to 18 whales annually during the spring hunt years ago before the arrival of the commercial whalers (Rainey, 1947). An excellent record of successful whaling captains and the dates on which they took whales has been compiled since 1949 by a resident of Point Hope, Mr. Herbert Kinneeveauk. Mr. David Brower of Barrow compiled data on whales taken there during 1928 to 1954 from family records. Durham[8/], the late D.C. Foote (pers. comm.), Maher and Wilimovsky (1963), Sonnefeld (1960), and the staff of the Naval Arctic Research Laboratory at Barrow[9/] have compiled data on the harvest from various sources.

8/ Durham, Floyd E. In press. The catch of bowhead whales (*Balaena mysticetus*) by Eskimos in the western arctic. Part I. Catch statistics. Contr. Sci., Los Angeles County Mus. Nat. Hist.

9/ Naval Arctic Research Laboratory Staff. 1972. Eskimo Whaling at Barrow, Alaska. Naval Arctic Res. Lab., Barrow, Alaska. Unpublished Report compiled by the staff, 12 December 1972. 24 pp.

The author is now searching the literature for data on the historical catch of bowhead whales by the aborigines of Alaska and the USSR (Tables 13 and 14) to augment information previously collected. A search of whaling vessel logbooks has also been initiated (J. Bockstoce, pers. comm.) to obtain data on the pelagic catch. When combined, these data will provide a means for estimating the size of the initial population of bowheads and, together with abundance information now being collected, provide a basis for determining the present status of the stock and for measuring the effects of the subsistence harvest on that stock.

Bowhead Whale Sightings

Some indication of the relative abundance of bowhead whales may be discerned by examining reports of the numbers of animals passing by the whaling villages during the spring migration. Bailey and Hendee (1926) wrote that Jim Allen, a Wainwright trader who had hunted whales for 25 years, said that more whales were observed there in 1922 than he had ever seen before. They concluded that the data available at that time indicated that the stock had increased substantially by the 1920's. Rainey (1947) concluded from his observations that they seemed to be increasing in numbers. Mansfield (1971) also believed that the bowhead population of the Bering, Chukchi, and East Siberian Seas appeared to be increasing. Burns (pers. comm.) stated that "In recent years continued slow increase was most noticeable in the numbers passing traditional hunting sites, and the increase was also indicated by the slowly increasing annual catches at these same sites, hunting as usual in the traditional manner." An Eskimo of Savoonga, on St. Lawrence Island, reported that an unusually large number of bowheads were observed migrating past the island during the spring of 1976. All of these observations apparently indicate that the bowhead population has been slowly increasing through the years.

Counts of Bowhead Whales

Past counts of bowheads passing whaling villages provide some indiation of the relative abundance of the whales in earlier years. Rainey (1940) reported scores of bowheads were seen passing Point Hope, and that he had seen at least 20 whales daily during the week of 12-19 April 1940. Foote[4/] made counts of bowheads passing Point Hope and recorded 127 in 1960, 49 (poor ice conditions) in 1961, and 177 in 1962. Rice (1974) commented

that the highest rate of migration that he had observed was at Barrow when 25 whales passed by during a 23 hour period on 11 May 1962, and added that over 100 whales were observed passing that village each year. Harry[10/] stated that in 1971, 500 bowheads were reported to have passed Wainwright during the first period of the whaling season. At Point Hope 28 bowheads were counted during one 24-hour period in April of 1971 (J. Bockstoce, pers. comm.).

More recent counts of bowheads passing Point Hope and Barrow have been made since the NMFS began monitoring the harvest. Although no systematic counts were made at Point Hope, whaling crews observed 59, 132, and 235 whales passing the village during the springs of 1974, 1975, and 1976, respectively. Seventy-five whales were observed passing Point Hope during one 24-hour period on 1 May 1976 (J. Bockstoce, pers. comm.). Durham[8/] states that in 1973 two Eskimo whalers at Barrow reported counts of 380 and 261 bowheads that passed that village during the spring migration, for which a conservative average may be 320 animals.

The OCSEAP crews made one autumn (1975) and one spring (1976) aerial survey, and a systematic count of bowheads was made at an ice-based station in the spring of 1976. A total of 357 whales was counted migrating up the lead past the ice-based station at Barrow (Table 27). Results of the aerial surveys conducted in the spring of 1976 are summarized in Table 28. Unusually severe conditions kept the pack ice next to shore all summer in 1975, and only two whales were sighted during the September October flights.

Fewer bowhead whales were counted in near-shore leads from the air than from the ice-based station, probably because less effective observational effort was achieved while flying than while on the ice. Thus it appears that counts from shore stations will be superior to counts from the air for delineating animal abundance in the near-shore leads. Aerial survey results west of Barrow indicate that bowheads migrate in the spring through near-shore leads, while east of Pt. Barrow they were seen in leads further offshore[11/].

10/ Harry, George Y., Jr. 1973. Arctic Whales and the Eskimos. U.S. Dept. Comm., NOAA, NMFS report submitted to Scientific Committee, International Whaling Commission, Document No. 23, 25th Meeting. 26 pp.

11/ Braham, H.W., and B.D. Krogman, 1977. Population biology of the bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whales in the Bering, Chukchi, and Beaufort Seas. Northwest and Alaska Fisheries Center Processed Report.

Table 27.--Numbers of bowhead whales, Balaena mysticetus, counted per day in open leads by the ice station counting crew and by Eskimos near Barrow, Alaska, from 25 April to 2 June 1976. Twenty-four hour watches were not maintained for all dates. Ice crew and Eskimo counts were not duplicates. No Eskimo counts were available after 20 May[1/]

Date	Number of animals seen		
	Ice crew	Eskimos	Total
25 April	3	2	5
29 April	11	6	17
30 April	7	10	17
1 May	17	3	20
2 May	3	6	9
3 May	1	1	2
5 May	11	9	20
6 May	16	19	35
7 May	8	1	9
8 May	4	1	5
9 May	2	0	2
10 May	0	1	1
11 May	0	0	0
12 May	0	0	0
13 May	21	7	28
14 May	5	0	5
15 May	11	3	14
16 May	18	11	29
17 May	26	9	35
18 May	52	9	61
19 May	1	0	1
21 May	4	-	4
22 May	19	-	19
23 May	0	-	0
24 May	9	-	9
25 May	1	-	1
26 May	6	-	6
31 May	1	-	1
1 June	1	-	1
2 June	1	-	1
Total	259	98	357

1/ Source: see Footnote 12.

Table 28.--Numbers of bowhead whales, *Balaena mysticetus* observed and miles of trackline flown by date during aerial surveys of the northeastern Chukchi and western Beaufort Seas, 30 April to 20 June, 1976. All flights were made from the Naval Arctic Research Laboratory, Barrow, Alaska 1/

Dates	Location of survey; Barrow to	Number of animals	Miles of trackline*
30 April	Pt. Hope	4	595
1 May	Wainwright and offshore leads	6	419
3 May	Icy Cape	3	250
8 May	Wainwright and east of Cape Simpson	34	260
9 May	Offshore leads east	5	161
12 May	Barter Island	2	600
14 May	Northeast of Barrow	0	60
15 May	Wainwright	18	225
19 May	Pt. Hope	3	270
20 May	Northeast of Barrow (offshore leads)	0	70
22 May	Wainwright (offshore leads); east to Lonely	4	352
24 May	Wainwright	3	150
28 May	Peard Bay	1	110
31 May	Wainwright	4	250
1 June	Pt. Hope	3	600
4 June	Northeast of Barrow	15	201
5 June	Wainwright	2	231
18 June	West of Barrow	0	602
19 June	Cape Lisburne	1	404
20 June	Barter Island	0	600
Totals		108	6,410

1/ Source: see Footnote 12.

* Trackline miles are for all miles flown, whether over open lead or shore fast ice; values are for nautical miles.

Estimates of Present Population

Rice[3] estimated a population size in 1964 of roughly 1,000 whales. On the basis of catch statistics for Point Hope from 1890 to 1964 (compiled by Foote, pers. comm.), and for Barrow from 1928 to 1960 (compiled by Maher and Wilimovsky, 1963), Rice (1974) concluded that although the Eskimos continued to hunt bowheads, there was no indication of change in the population size during this century. Fay (1975) states that the present population is believed to be about 1,000 and is thought to be increasing steadily. Durham[7] considered 2,500 a reasonable estimate of the population, and Harry [10] estimated the population to be between 1,000 and 3,000 animals in 1973. Mitchell (1974b) concluded that on the basis of the observed sustained kill and sightings by hunters and others, the western Arctic stock appears to be recovering well and must be counted in the high hundreds or low thousands. Sergeant and Hoek (1974) concluded that many of the whales migrating past Barrow spend their summers in the eastern Beaufort Sea north of the MacKenzie River delta and west of Banks Island, and estimated the population in this sector to number in the low hundreds. In a recent report Scheffer (1976) places the population of bowheads at around 2,000 whales.

A preliminary analysis of data obtained by OCSEAP surveys in 1976 suggests that as many as 800 bowhead whales may have migrated past Barrow during the spring survey period (25 April-2 June); given the protracted migration period (March through July) and the evidence of sightings and past catches of bowheads in the Chukchi Sea during the summer, it is unlikely that this number totally accounts for the current stock size.[11] Further examination of survey methodology will be required before any conclusions can be made regarding the statistical reliability and accuracy of abundance estimates obtained from these data. Preliminary evidence suggests that the number of sightings will vary from year to year depending on ice and other environmental conditions. Thus, repeated surveys in subsequent years and in other areas will be required before questions concerning precision and accuracy of estimates of total bowhead abundance might be answered.

DISCUSSION OF THE HARVEST

Several factors are probably responsible for the increased kill of bowhead whales by Alaskan Eskimos in recent years. From 1946 to 1969 the kill averaged about 10 whales annually. Since 1970 the annual take has averaged 29. Reasons for this increasing catch since 1970 are not obvious but several factors may be contributory.

The number of whaling crews has generally increased during recent years (Table 29). This trend would account for the observed increase in the catch of bowhead whales and might be correlated to the economic impacts of the Alaska Land Claims Settlement Act (authorized payments extinguishing all land claims of Alaskan natives) and the exploitation of north slope petroleum. Traditionally, the prestigeous status of whaling captain was attained by a combination of skill, intelligence, energy, and astute business ability (Rainey, 1947). Although some captains inherited their equipment, the qualities listed were necessary for them to establish and maintain whaling crews. This situation when Eskimos had little income, resulted in a fairly stable number of experienced captains and crews. However, the rising economy of the Eskimos in recent years has provided capital for new whaling captains, often inexperienced young men, to establish crews and to buy equipment and bombs. An abundance of bombs, when combined with inexperience, can encourage careless aiming, and long, possibly, unnecessary shots. All of these factors can be expected to result in an increasingly larger annual kill and in loss of struck whales.

It might be argued that the growing annual kill reflects an increased abundance of bowhead whales. Although OCSEAP data collected during the first year of surveys are insufficient to be indicative, other investigators previously cited in this report have concluded that the population is increasing at an unknown rate. Several Eskimos remarked about the large numbers of whales sighted during 1976, and correctly predicted that they were going to take many whales this year. Additionally, the prevalence of young animals in the catch might indicate a healthy, increasing population. It follows that an increase in the number of whales would result in an increased kill, especially when accompanied by an increase in whaling effort.

Weather also affects the number of whales taken. Whaling is conducted under severe Arctic environmental conditions important in their effect on hunter success. If leads open further out than that near shore, a majority of the whales may follow a route inaccessible to the whalers. An ideal near-shore lead would be 91.4 to 183 m (100 to 200 yards) wide and remain open during most of the season. However, constantly moving ice often closes the lead and presents considerable danger to the crews. Camps and equipment must frequently and quickly be moved to shore to prevent their loss to crushing ice. Strong offshore winds sometimes cause the shorefast ice on which the whaling crews are camped to, break off and drift seaward, and strong winds reduce the whalers ability to see whales and make the water rough and dangerous for their small boats. Occasional fog and snowstorms reduce observations and present considerable risk to crews in pursuit ot whales. These conditions are primarily responsible for a variable number of crews actually engaged in whaling from day to day. That environmental conditions

Table 29.--Number of Alaskan Eskimo crews participating in spring whaling in recent years

Location	Date	Number
Barrow	1971	25
	1972	27
	1973	28
	1974	21
	1975	30
	1976	36
Point Hope	1973	11
	1974	10
	1975	13
	1976	14
Wainwright	1973	6
	1974	2
	1975	4
	1976	8
St. Lawrence Island	1974	8
	1975	23
	1976	-
Kivalina	1974	5
	1975	5
	1976	3
Wales	1974	-
	1975	-
	1976	2

can therefore significantly influence the success of Eskimo whalers from year to year was shown by the reduced kill in 1975 (Table 12), when the most severe sea-ice conditions of the past 23 years occurred (Barnett, 1976), and by a record high kill in 1976 during favorable weather, particularly in the autumn.

An observed change in whaling methodology, particularly at Barrow, may have resulted in an increase in the number of whales being struck but lost. Some unknown proportion of these animals no doubt die from their injuries. Traditionally a harpoon with attached float is first fired into the animal from a darting gun. If a second bomb is necessary, it is usually fired almost immediately from another darting gun, but without attached harpoon. If more bombs are needed to kill the whale, or if it is not safe for the boat to approach the wounded animal, then a shoulder gun is used. Considerable skill and courage are required to employ the darting gun, and recent observations indicate that whales are now often struck first with bombs fired from shoulder guns. Although the whale is usually injured, it can frequently elude its pursuers unimpeded by a harpoon with attached line and float. This practice no doubt results in numerous whales being struck and lost.

Reports by other authors on the numbers of whales that have been struck and lost vary considerably. Our investigation has shown that from 1973 through 1976, 99 whales were struck and lost and 13 were killed but not recovered. Thus, 112 were lost, compared to 120 killed and recovered. Our data show that approximately one-half (48 percent) of all whales struck were wounded and lost, a figure considerably less than that reported by others.

The number of struck and lost whales that die from their wounds can only be estimated. Some bombs fired into whales fail to explode, and others pass clear through and explode in the water. Judging from the relatively small size of the bombs used by the Eskimo whalers, which are about the size of Discovery tags used in whale marking studies, and the small amount of powder used in them (100 grams), some of these injuries may not be fatal (shoulder gun bombs are 46 cm (18 inches) and darting gun bombs are 38 cm (15 inches) in length; and both types are 2 cm (0.75 inch) in diameter).

Several factors contribute to the problem of striking but not recovering whales, of which the most important may be failure of the bomb to explode after it enters the whale. The

weak points of bombs are the fuse and the keeper (Figure 6). The keeper, a small piece of wood is designed to break when the bomb is fired, allowing the firing pin to fall and strike the cap, thereby igniting the fuse, which in turn burns into the lower part of the bomb and ignites the powder. Keepers supplied with the bombs are made of balsa wood. Substitute keepers, however, are fashioned from wooden matches when, for various reasons, the bombs are reloaded. These new keepers frequently do not break when the missile is fired and the bomb therefore fails to explode as intended. Bombs may also fail to explode should the fuse fail to ignite or if the powder becomes damp. Redesigning of the bomb and its component parts with ease and safety in assembly under rigorous field conditions in mind, may prevent loss of some struck whales.

Improvements in the weaponery presently used in the fishery might be effective in reducing the number of whales that are struck and lost. Guns and bombs used by the whalers in taking bowheads are manufactured by the Naval Gun Company, Doylestown, Pennsylvania[12/], under contract to the Alaska Native Industries Cooperative Association (ANICA), the only authorized source of such equipment. The guns and bombs have continued in use almost unchanged since their introduction by commercial whalers in the late 19th century. Numerous malfunctions of the bombs certainly contribute to the problem of whales struck and lost.

In summary, many factors are responsible for the increasing numbers of whales taken and those wounded and lost. Although the annual take of bowheads varied erratically in past years, it remained generally stable at a level which apparently allowed the population to increase. However, in the 1970's a considerable increase occurred in the harvest. Because the size of the bowhead population is as yet undetermined, the increase in the annual kill cannot be readily evaluated but is of great concern.

12/ Reference to trade name(s) in this report does not imply endorsement of commercial product(s) by the National Marine Fisheries Service, NOAA.

FUTURE RESEARCH

The Scientific Committee of the International Whaling Commission (IWC) recommended at the June 1976 meeting (1) that a thorough examination of early whaling history, including inspection of logbooks, be made to provide information on past population levels; (2) that marking studies be done to help assess mortality rates of struck but lost whales; (3) that an assessment of current population status be made; and (4) that a collection or compilation of better information on sex, length, maturity, and age of captured whales be assembled. In addition, the Scientific Committee strongly recommended that necessary steps be taken to limit expansion of the fishery and to reduce the loss rate of struck whales. The IWC concurred with the recommendation of its Scientific Committee, and, in a resolution to the contracting governments, urged them to implement those recommendations as soon as possible.

In 1977 biologists will again be stationed for the spring hunt at the two major whaling villages, Point Hope and Barrow, and at Barrow in the fall to gather information on bowhead whales taken. In addition, an observer will visit St. Lawrence Island during the spring whaling season to obtain information on the hunt at the villages of Gambell and Savoonga. In the past we have had to depend on visitors to the island to provide us with information on whaling activities there.

We will establish an ice-based counting station at Point Hope in 1977, as well as at Barrow, in order to make better estimates of the numbers of bowhead whales migrating northward. Because some whales migrating past Point Hope may travel to the north Chukchi Sea by a route other than past Barrow, a count obtained at Point Hope may detect those animals and permit a more accurate enumeration of the population.

Future aerial surveys should enable us to determine how bowheads arrange themselves in time and space as they move into and out of the Arctic Ocean. Whereas ice-based surveys give more complete whale counts, aerial surveys have been invaluable for delineating migratory patterns and behavior, thus allowing better interpretation of counts from the ice. Continued collection of data in the future from ice-based counting stations and from the air will significantly contribute towards our understanding of bowhead whale distribution and abundance.

During the spring of 1978 we plan to expand our observations of the Eskimo harvest of bowheads to all villages actively engaged in whaling. In that year, two observers will for the first time be stationed on St. Lawrence Island throughout the whaling season because the potential take of these

animals is great in that area, and whaling methods employed by the Eskimos there are unique among all the whaling villages of Arctic Alaska. The crew at Barrow will be augmented to provide sufficient people to monitor the 36 whaling crews active at that village. One biologist will also visit villages during the whaling season where observers have never been stationed to obtain all information possible relating to the harvest and biology of bowhead whales. With these data we can improve our estimates of whales killed and lost and those struck but lost, as well as increase our collection of data on age and sex composition of the catch.

Beginning in 1978, we also plan to start a project of examining the logbooks of early whaling vessels to determine the pelagic catch of bowhead whales by commercial whalers. In addition, a search of the literature will provide an estimate of the annual catch by Eskimos in the past. These data will provide a statistical basis for estimating the original size of this population.

Plans are now being made for conducting a bowhead whale marking program as soon as a tag suitable for the rigorous conditions of the Arctic can be developed. The ice-filled waters inhabited by these whales require a tag that can survive the harsh physical conditions of this environment. Frequent physical contact by these animals with floating ice dictates that the tags will have to be well anchored in the body of the whale, with a minimum projection from the body to reduce damage from the ice. Information produced by a marking program will augment known information on the abundance and distribution of bowhead whales.

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Weather data for Barrow was provided by the NOAA Weather Service facility located at that village.

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Finally, I wish to express my gratitude to the many scientists whose interest and cooperative research involves ongoing studies that will enrich our knowledge of the biology of the bowhead whale. To date, one study on hearing has been partially completed by Dr. G. Fleischer (1976), Tuebinger University, Tuebinger, West Germany. Mr. Lloyd Lowry, Alaska Department of Fish and Game, Fairbanks, identified food items found in stomach contents of bowhead whales. When the various cooperative studies are completed, the findings will be included in future NMFS reports on the bowhead.

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FIGURES

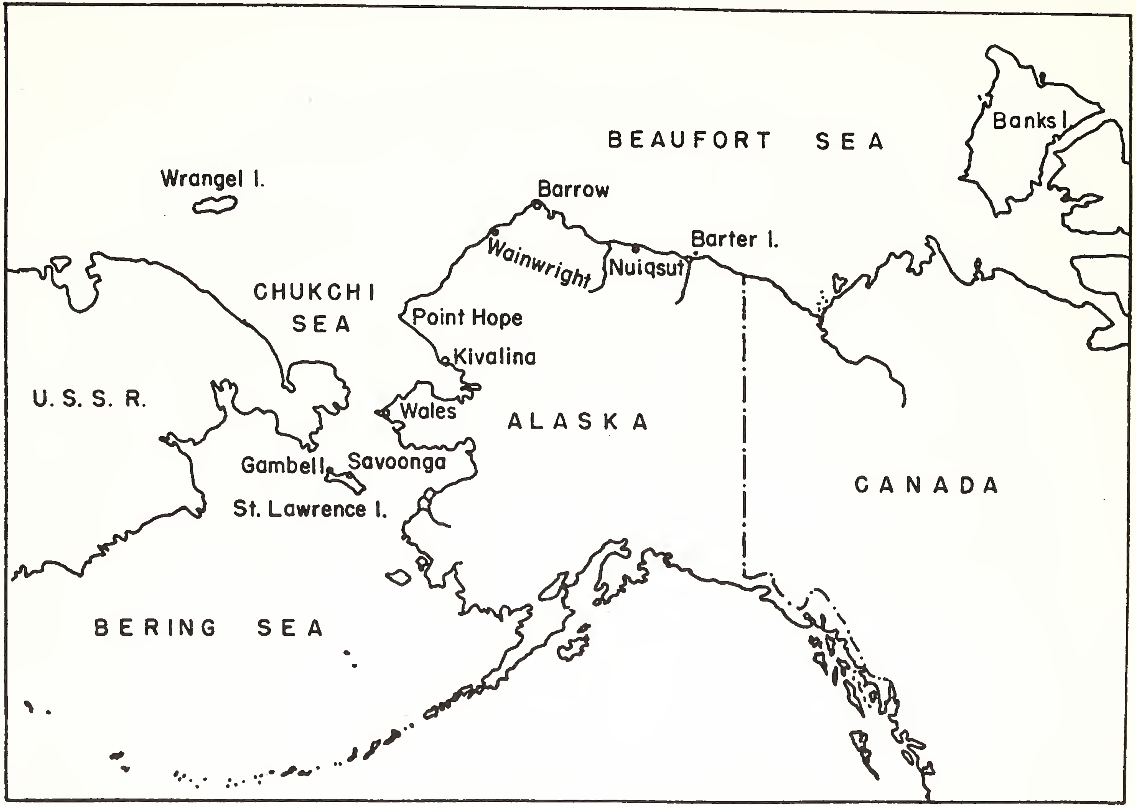


Figure 1. Map of bowhead whale study area.

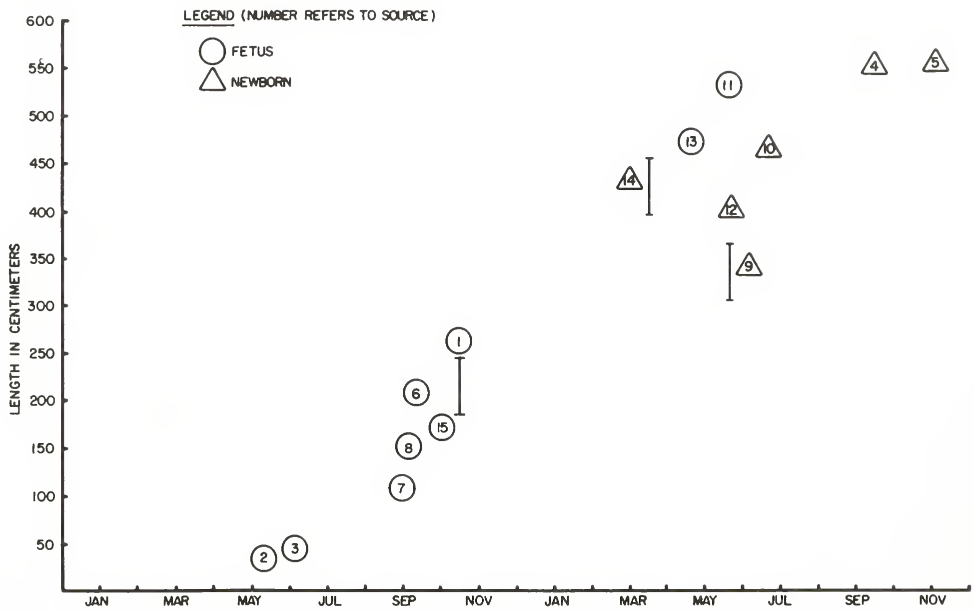


FIGURE 2. GROWTH RATE FOR BOWHEAD WHALE FETUSES AND NEWBORN CALVES.

Figure 2. Continued: sources of data on growth for fetuses and newborn of the bowhead whale.

Number	Date	Age	Length(cm)	Source
1.	Autumn	Fetus	183-244	Durham, F., Unpub. Rept. 5/
2.	10 May	Fetus	13	Durham, F., Unpub. Rept. 5/
3.	2 June	Fetus	25	Durham, F., Unpub. Rept. 5/
4.	Autumn	Est. 6 mo.	549	Durham, F., Unpub. Rept. 5/
5.	30 Sept.	Newborn	549	Slijper, 1962.
6.	12 Sept. 1852	Fetus	190	Allen, 1973.
7.	1 Sept. 1882	Fetus	91	Murdoch, 1885.
8.	3 Sept. 1976	Fetus	131	Marquette, (this report).
9.	20 May 1954	Est. 1-2 wks	305-366	Maher & Wilimovsky, 1963.
10.	6 June 1973	Newborn	460	Durham, F., Unpub. Rept. 7/
11.	22 May 1925	Fetus	518	Richards, E.A., 1949.
12.	6 May 1843	Newborn, umbilical still attached	396	Eschricht & Reinhardt, 1866.
13.	20 Apr. 1801	Fetus	457	Eschricht & Reinhardt, 1866.
14.	18 Mar. 1807	Newborn	396-457	Eschricht & Reinhardt, 1866.
15.	Autumn 1916	Fetus	152	Brower, C.D., Unpub. rept. 6/

Figure 3. Each whaling crew has a seal-skin covered boat (umiak) and tent. Snowmobiles have largely replaced the dog team for transportation.

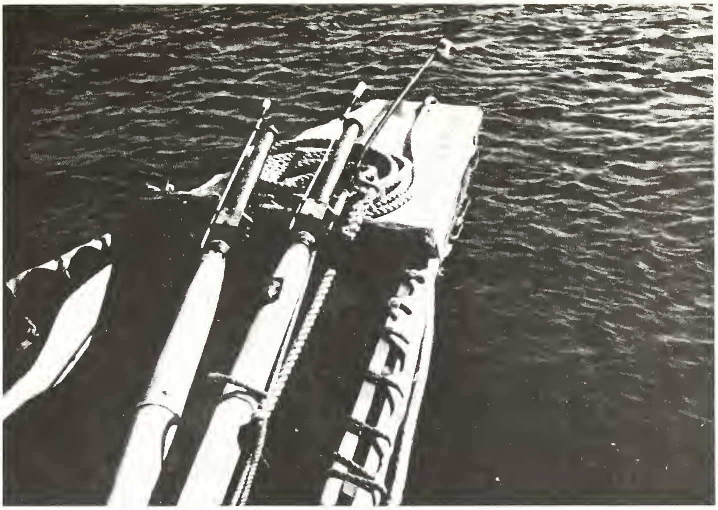


Figure 4. Two darting guns in position in the bow of the skin boat are ready for instant use. One gun has a harpoon attached that is secured to a float by a line about 61m (200 feet) in length.

Figure 5. Two shoulder guns have been placed so that they can be easily picked up. The bomb has been removed from the gun in the foregroundto show its size.

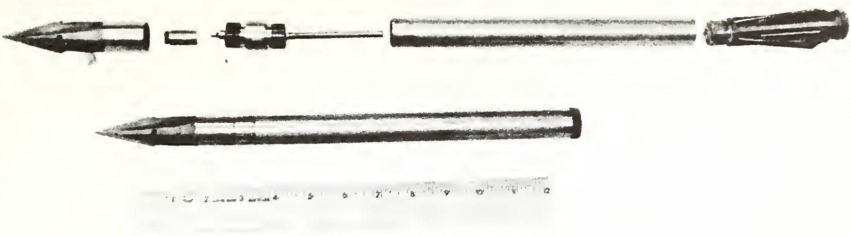


Figure 6. Exploded view of bomb used in shoulder guns. Bomb fired from darting guns (bottom) is identical except it is about 8 cm (3 inches) shorter because flight-vanes are not needed.

Figure 7. Harpoon with toggle-head in position for thrusting into whale.

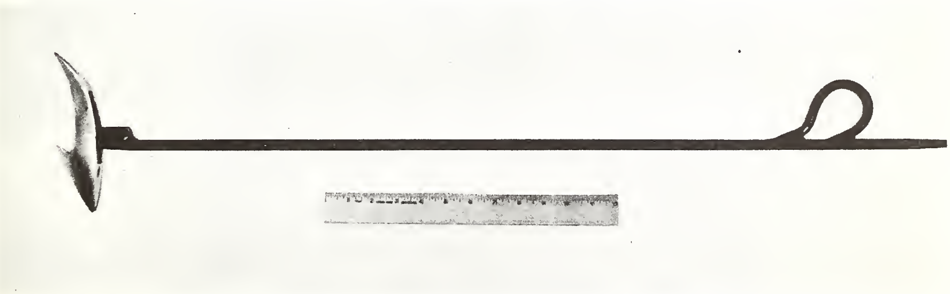


Figure 8. Harpoon head rotates to position illustrated as result of tension caused by attached line and float, after harpoon has entered body of the whale. The toggle-head greatly reduces chance that the harpoon may be pulled out, perhaps resulting in loss of the whale.

Figure 9. Skin-deep cuts are made by a skilled flensor before whale is removed from the water to indicate how specific sections of the whale are to be cut and removed.

Figure 10. Most of the bowhead whales taken by the Eskimos are pulled up onto the ice for butchering by means of black and tackle anchored to an ice bridge.

Figure 11. Two large whales pulled onto the ice for butchering.

Figure 12. Butchering of the whale has been completed, except for the side of baleen that is about to be removed.

APPENDIX TABLE

Measurements of body proportions (in centimeters) of
bowhead whales harvested by Alaskan natives, 1973-1976.

Specimen No.	4461	4462	4463	4464	4465	4466	4467
1. Sex	M	M	F	F	M	M	F
2. Snout to notch of flukes	823	670	915	915	820	910	1036
3. Snout to center of blowhole	168	--	--	--	--	240	--
4. Snout to center of eye	254	--	--	--	--	280	--
5. Snout to gape	--	--	--	--	--	--	--
6. Snout to ear	--	--	--	--	--	--	--
7. Snout to flipper insertion	315	--	--	--	--	--	--
8. Notch of flukes to center of anus	223	--	--	--	--	--	--
9. Notch of flukes to genital aperature	279	--	--	--	--	--	--
10. Notch of flukes to genital aper. (ant.)	--	--	--	--	--	--	--
11. Mammary slits, distance between	--	--	--	--	--	--	--
12. Notch of flukes to umbilicus	--	--	--	--	--	--	--
13. Flukes, total span	245	--	--	--	--	307	--
14. Fluke length, tip to notch	--	--	--	--	--	--	--
15. Fluke width at insertion	--	--	--	--	--	65	--
16. Girth behind flippers	508	--	--	--	--	--	--
17. Girth, maximum	--	--	--	--	--	--	--
18. Girth, anterior of flukes	--	--	--	--	--	--	--
19. Flipper, anterior length	122	122	122	124	--	127	--
20. Flipper, posterior length	94	99	94	100	--	94	--
21. Flipper, maximum width	53	61	63	60	--	63	--
22. Blowhole length	--	--	--	--	--	--	--
23. Blowhole dist. apart ant.	--	--	--	--	--	--	--
24. Blowhole dist. apart post.	--	--	--	--	--	--	--
25. Baleen, total right side	--	--	--	--	--	--	--
26. Baleen, total left side	--	--	--	--	--	--	--
27. Baleen, maximum length	155	156	160	154	--	183	--
28. Skin thickness	--	--	--	--	--	--	--
29. Blubber thickness	15	--	--	--	--	15	--
30. Skull length	277	292	310	318	--	310	--
31. Skull width	150	150	160	145	--	155	--
32. Mandible length (straight)	274	287	314	310	--	314	--

	4468	4469	4470	4471	4472	4473	4474	4475	4476	4477	4478	74H1
1.	F	-	F	F	M	M	F	F	M	F	M	M
2.	823	--	855	884	610	--	975	825	762	1525	460	813
3.	--	--	165	172	--	--	--	178	--	264	74	--
4.	--	--	210	242	--	--	--	220	--	372	102	--
5.	--	--	217	247	--	--	--	218	--	385	104	--
6.	--	--	--	267	--	--	--	--	--	414	120	--
7.	--	--	--	278	--	--	--	247	--	427	133	--
8.	--	--	233	240	--	--	--	275	--	405	118	--
9.	--	--	259	--	--	--	--	--	--	--	142	--
10.	--	--	--	--	--	--	--	--	--	--	195	--
11.	--	--	--	--	--	--	--	--	--	--	--	--
12.	--	--	--	--	--	--	--	--	--	730	215	--
13.	--	--	264	254	250	--	280	254	--	--	137	--
14.	--	--	--	--	--	--	--	--	--	--	--	--
15.	--	--	--	66	--	--	72	64	--	--	38	--
16.	--	--	--	--	--	--	--	520	--	--	--	--
17.	--	--	--	--	--	--	--	--	--	--	--	--
18.	--	--	--	--	--	--	--	--	--	--	--	--
19.	--	--	117	127	--	137	127	115	--	234	75	126
20.	--	--	92	104	--	115	97	85	--	206	56	104
21.	--	--	56	60	--	74	58	52	--	127	32	60
22.	--	--	--	--	--	--	--	--	--	--	--	--
23.	--	--	--	--	--	--	--	--	--	--	--	--
24.	--	--	--	--	--	--	--	--	--	--	--	--
25.	--	--	--	--	--	--	--	--	--	--	--	--
26.	--	--	--	--	--	--	--	--	--	--	--	--
27.	--	--	--	--	69	175	140	69	127	--	--	85
28.	--	--	--	--	--	--	--	--	--	--	--	2.6
29.	--	--	26	30.5	--	--	25	--	--	30	5.3	18
30.	--	--	--	268	248	355	280	260	265	414	134	--
31.	--	--	--	156	125	170	150	150	140	--	71	--
32.	--	--	--	267	250	346	285	--	272	--	--	254

	74H2	74H3	74H4	74H5	74H6	74H7	74B1	74B2	74B3	74B4	74B5	74B6
1.	M	F	M	M	-	-	-	M	F	M	F	M
2.	869	757	1524	1550	1219[1/]	914[1/]	975	813	1135	1385	724	671[1]
3.	--	169	--	--	--	--	--	--	--	--	--	--
4.	263	222	--	--	--	--	--	--	--	--	--	--
5.	--	--	--	--	--	--	--	255	--	--	--	--
6.	--	--	--	--	--	--	--	--	--	--	--	--
7.	--	--	--	--	--	--	--	--	--	--	--	--
8.	240	--	--	--	--	--	--	--	--	338	--	--
9.	--	--	--	--	--	--	--	--	--	505	--	--
10.	--	--	--	--	--	--	--	--	--	--	--	--
11.	--	25	--	--	--	--	--	--	--	--	--	--
12.	405	--	--	--	--	--	--	--	--	--	--	--
13.	--	--	--	--	--	--	--	--	305	--	--	--
14.	--	--	--	--	--	--	--	--	152.5	--	--	--
15.	70	70	--	--	--	--	--	--	70	--	--	--
16.	--	--	--	--	--	--	--	--	--	--	--	--
17.	--	--	--	--	--	--	--	--	--	--	--	--
18.	--	--	--	--	--	--	--	--	--	--	--	--
19.	126	113	--	--	--	--	--	123	117	254	--	--
20.	92	81	--	--	--	--	--	104	99	191	--	--
21.	58	57	--	--	--	--	--	62	60	137	--	--
22.	--	--	--	--	--	--	--	14	--	--	--	--
23.	--	--	--	--	--	--	--	--	--	--	--	--
24.	--	--	--	--	--	--	--	--	--	--	--	--
25.	279	280	--	--	--	--	--	321	298	--	--	--
26.	288	--	--	--	--	--	--	--	--	--	--	--
27.	118	66	--	--	--	--	129	97	57	--	60	--
28.	2	2.5	--	--	--	--	--	2	2	--	2	--
29.	15	19	--	--	--	--	--	22	24	--	17	--
30.	--	--	--	--	--	--	320	247	268	--	--	221
31.	--	--	--	--	--	--	180	149	155	--	--	115
32.	283	230	--	--	--	--	314	264	263	--	--	217

	75H1	75H2	75H3	75H4	75B1	75B2	75B3	75B4	75B5	75B6	75B7	75B8
1.	-	-	F	M	F	M	F	-	M	F	F	F
2.	1097 1/	610 1/	846	1158	795	691	927	800 1/	854	1620	784	1111
3.	--	--	207	--	210	163	--	--	220	423	173	333
4.	--	--	242	--	--	202	--	--	260	532	233	392
5.	--	--	--	--	--	212	--	--	270	--	242	397
6.	--	--	--	--	--	183	--	--	290	541	--	432
7.	--	--	--	--	--	232	--	--	310	--	--	526
8.	--	--	--	--	--	186	--	--	236	397	215	--
9.	--	--	215	--	--	249	--	--	321	473	224	--
10.	--	--	--	--	--	--	--	--	--	--	--	--
11.	--	--	--	--	--	--	--	--	--	--	--	--
12.	--	--	--	--	--	--	--	--	431	--	274	--
13.	--	--	--	--	263	220	--	--	254	551	228	390
14.	--	--	--	--	--	--	--	--	--	--	--	--
15.	--	--	--	73	62	60	--	--	68	139	58	84
16.	--	--	--	--	--	535	--	--	508	--	--	700
17.	--	--	--	--	--	535	--	--	514	--	--	--
18.	--	--	--	113	--	--	--	--	98	190	106	--
19.	--	--	126	100	108	107	138	--	130	256	120	177
20.	--	--	--	92	78	78	98	--	100	202	92	125
21.	--	--	53	64	52	52	66.5	--	56	138	51	86
22.	--	--	--	--	--	--	--	--	--	--	--	--
23.	--	--	--	--	--	--	--	--	--	--	--	--
24.	--	--	--	--	--	--	--	--	--	--	--	--
25.	--	--	--	--	--	--	323	--	335	--	274	324
26.	--	--	275	--	--	--	--	--	--	--	--	--
27.	95	--	90	--	--	45	155	--	126	313	70	221
28.	--	--	2.5	2.2	--	--	--	--	2.3	2.2	2.5	2.5
29.	--	--	20	18	15	16	16	--	15.5	32	17.5	17.2
30.	--	--	--	--	293	219	333	289	276	598	276	415
31.	--	--	--	--	136	117	184	140	153	214	153	212
32.	--	--	255	--	295	218	333	276	271	562	243	421

	75B9	75B10	76H1	76H2	76H3	76H4	76H5	76H6	76H7	76H8	76H9	76H10
1.	-	M	-	M	F	M	F	M	F	F	F	F
2.	715	1402	792[1/]	1021	1321	1120	853	1468	846	848	825	889
3.	--	350	--	253	334	--	--	--	--	213	--	212
4.	--	442	--	314	418	367	--	--	--	273	--	262
5.	--	448	--	--	--	--	--	--	--	--	--	--
6.	--	--	--	--	--	--	--	--	--	--	--	--
7.	--	--	--	--	475	--	--	--	--	--	--	--
8.	--	334	--	255	--	294	343	256	--	242	--	240
9.	--	450	--	353	--	380	363	472	--	249	--	248
10.	--	--	--	421	--	511	--	--	--	--	--	277
11.	--	--	--	--	--	--	24	--	--	16	--	20
12.	--	--	--	--	505	525	--	--	--	394	--	400
13.	--	498	--	--	--	--	--	--	--	--	--	--
14.	--	--	--	--	--	--	--	--	--	--	--	--
15.	--	123	--	83	--	--	--	122	--	--	--	--
16.	--	--	--	--	674	--	--	--	--	360	--	--
17.	--	--	--	--	--	572	--	--	--	384	--	--
18.	--	--	--	--	--	--	--	--	--	--	--	--
19.	--	238	--	150	--	--	--	223	130	118	--	124.5
20.	--	188	--	116	--	--	--	175	115	95	--	96
21.	--	120	--	63	--	--	--	111	63	53	--	60
22.	--	--	--	20	23	--	--	--	--	--	14	--
23.	--	--	--	5	5.5	--	--	--	--	--	4	--
24.	--	--	--	17	22	--	--	--	--	--	12.5	--
25.	--	--	--	--	--	285	--	--	--	--	--	307
26.	--	--	--	346	329	--	320	283	--	--	--	--
27.	--	287	--	138	212	200	--	256	--	--	--	145
28.	--	--	--	2	2	--	--	2	2.5	--	--	2
29.	--	--	--	16	22	--	--	21.5	22	--	--	15
30.	233	465	--	--	--	--	--	--	--	--	--	--
31.	123	250	--	--	--	--	--	--	--	--	--	--
32.	226	464	--	350	445	384	--	430	--	285	267	--

	76H11	76H12	76B1	76B2	76B3	76B4	76B5	76B6	76B7	76B8	76B9	76B10
1.	F	M	M	M	-	-	F	M	M	M	M	M
2.	808	762	750	1144	796	1136	750	1235	980	1370	1070	1100
3.	190	225	--	320	--	265	--	330	235	--	--	295
4.	250	242	--	389	226	347	--	400	303	--	--	355
5.	--	--	--	360	256	350	--	--	310	--	--	366
6.	--	--	--	480	286	--	--	--	343	--	--	403
7.	--	--	--	420	--	342	--	--	--	--	--	--
8.	216	198	--	265	210	295	--	337	243	360	294	308
9.	220	247	--	350	--	371	--	454	310	490	364	370
10.	--	324	--	--	--	--	--	--	--	--	--	--
11.	--	--	--	--	--	--	--	--	--	--	--	--
12.	--	341	--	455	--	508	--	--	--	--	--	518
13.	--	--	--	323	274	366	--	362	289	435	--	371
14.	--	--	--	--	--	--	--	--	--	--	--	--
15.	--	75	--	74	63	86	--	82	74	100	84	90
16.	--	420	--	736	380	452	--	--	--	--	--	--
17.	--	--	--	--	--	--	--	--	--	--	--	--
18.	--	--	--	130	--	--	--	--	--	--	--	--
19.	--	111	--	164	108	162	--	204	134	218	150	189
20.	--	83	--	120	84	126	--	147	--	163	123	140
21.	--	51	--	82	49	75	--	98	74	115	79	92
22.	--	14	--	--	--	--	--	--	--	--	--	--
23.	--	3.5	--	--	--	--	--	--	--	--	--	--
24.	--	12.5	--	--	--	--	--	--	--	--	--	--
25.	304	294	--	--	270	--	281	--	--	--	--	342
26.	--	--	--	315	--	--	280	--	--	--	--	--
27.	123	--	--	226	133	--	137	237	--	--	--	--
28.	2	2.5	2	2	--	--	--	--	2	2	2	3
29.	17	12	19	20	--	--	--	--	19.5	25	21	21
30.	--	--	328	--	278	290	287	447	--	--	--	390
31.	--	--	164	--	--	--	140	--	--	--	--	--
32.	262	250	315	419	275	--	292	437	328	--	--	380

	76B11	76B12	76B13	76B1F	76B2F	76B3F	76B4F	76B5F	76B6F	76B7F	76B8F
1.	F	F	F	M	M	M	M	F	F	F	M
2.	685 1/	854	1158	1650 1/	1630 1/	1620 1/	1650 1/	1730	1600	1430	1408
3.	--	197	--	--	--	--	--	--	--	390	410
4.	--	235	--	--	--	--	--	--	--	495	480
5.	--	240	--	--	--	--	--	--	--	--	--
6.	--	260	--	--	--	--	--	--	--	--	530
7.	--	310	--	--	--	--	--	--	--	--	--
8.	--	220	306	--	--	--	--	--	--	--	--
9.	--	230	316	--	--	--	--	--	--	--	--
10.	--	--	--	--	--	--	--	--	--	--	--
11.	--	--	--	--	--	--	--	--	--	--	--
12.	--	410	527	--	--	--	--	--	--	--	--
13.	280	245	318	--	--	--	--	--	575	--	--
14.	--	--	--	--	--	--	--	--	--	--	--
15.	72	60	86	--	--	--	--	--	140	--	--
16.	--	650	--	--	--	--	--	--	--	--	--
17.	--	690	--	--	--	--	--	--	--	--	--
18.	--	--	--	--	--	--	--	--	--	--	--
19.	121	109	154	--	--	--	--	--	255	240	280
20.	87	91	109	--	--	--	--	--	210	180	200
21.	57	52	87	--	--	--	--	--	135	115	130
22.	--	--	--	--	--	--	--	--	--	--	--
23.	--	--	--	--	--	--	--	--	--	--	--
24.	--	--	--	--	--	--	--	--	--	--	--
25.	--	--	--	--	--	--	--	--	--	--	--
26.	--	303	--	--	--	--	--	--	--	--	--
27.	--	79	--	--	290	?	--	--	--	280	230
28.	--	2.5	--	--	--	--	--	--	--	--	--
29.	--	21.5	13.5	--	--	--	--	--	--	--	--
30.	270	255	--	--	--	--	--	--	--	--	--
31.	--	--	--	--	--	--	--	--	270	--	--
32.	--	245	--	--	--	--	--	--	580	--	--

	76B9F	76B10F
1.	M	M
2.	1525	1320
3.	--	410
4.	480	470
5.	--	--
6.	--	--
7.	560	--
8.	400	--
9.	540	--
10.	--	--
11.	--	--
12.	710	--
13.	--	--
14.	--	--
15.	123	--
16.	--	--
17.	--	--
18.	--	--
19.	270	235
20.	190	190
21.	150	120
22.	--	--
23.	--	--
24.	--	--
25.	--	--
26.	--	--
27.	245	242
28.	--	--
29.	--	--
30.	--	--
31.	--	--
32.	--	--

1/. Estimate of length provided by the Eskimos.

APPENDIX F

SC/29/Doc. 6

On the risks associated with different harvesting strategies.

J.R. Beddington.*

Introduction

Attention has already been drawn to the risks associated with operating a management strategy based upon a mathematical model whose functional form is unknown Holt (1976). The associated problem of management where the parameters of the chosen model are but only approximately known has also been recognised Allen (1976). In this paper I consider a problem complementary to both these areas and assume that both the parameters of a model and its functional form are known, but that the model is a deterministic approximation to what is essentially a stochastic process.

I consider how different management strategies will have associated with them different risks of driving whale stocks beyond the MSY level to become protected stocks. Clearly recognition that both the functional form and parameters of the model are unlikely ever to be known with much certainty implies that this analysis is conservative in that it underestimates the actual risks involved in management.

In the first part of the paper I consider a general mathematical model of the type used for assessing quotas for Baleen whales. The equilibrium conditions associated with different harvesting regimes are considered and the idea is introduced that different equilibria will have different degrees of stability. The relative stability of different strategies may then be used as an index to estimate the likely risks of driving a stock beyond MSY in a randomly varying environment. In the second part of the paper these somewhat abstract ideas are given some substance by considering the Sei Whale model (IWC SC 1976). In the final part attention is drawn to the differences in stability obtained under quota and effort management. It is shown that effort management is considerably more stable.

Model and Analysis

The usual mathematical form of the model of Baleen whales is as a time delayed non linear difference equation relating the stock density in year t+1 N_{t+1} to that in previous years N_{t-i} i=0,k. The form used is

$$N_{t+1} = F_1(N_{t-k}). \tag{1}$$

$F_1(N_t)$ specifies the number surviving from year t-t+1 and $F_2(N_{t-k})$ the recruitment to the stock from the breeding population k years previously, k is thus the age of sexual maturity. (Allen 1963, Clark 1976). With a harvest quota C_t equation (1) may be rewritten

$$N_{t+1} = F_1(N_t) + F_2(N_{t-k}) - C_t \tag{2}$$

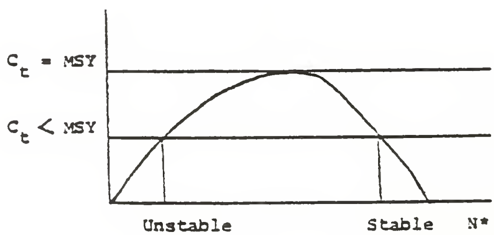
Equilibria for this model for any C_t are found by writing $N_{t+1} = N_t = N_{t-k} = N^*$ giving $C_t = F_1(N^*) + F_2(N^*) - N^*$ (3)

MSY is then obtained as the maximum of (3) and occurs at $N^* > 0$ where

$$F_1'(N^*) + F_2'(N^*) - 1 = 0$$

For most of the usual functional forms of F_1 and F_2, only where C_t = MSY does (3) have a single root in N^*, usually there are two roots corresponding to a lower unstable equilibrium and upper stable equilibrium. This is illustrated in Fig. 1.

Figure 1



It is important to note that at MSY the equilibrium is stable to perturbations above MSY stock level, but unstable to perturbations below it. Formal analysis of the stability properties of the equilibria of the

model are deferred to the Appendix where it can be shown that we can write an equation in the deviations from equilibrium X_t such that

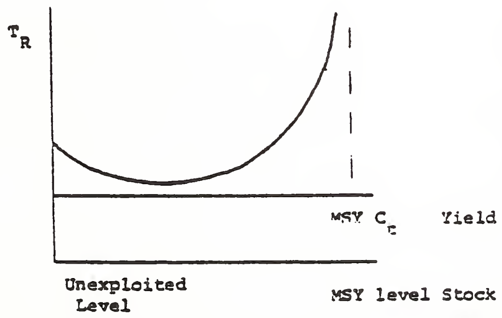
$$X_{t+1} = zX_t. \tag{4}$$

Where k is the root of largest absolute size of the characteristic equation derived from (2). Clearly $|k| < 1$ is the condition for stability of the equilibrium. Note however that as $|k| \to 0$ the damping rate of the perturbations increases and the time taken for X_t to reach some arbitrary small value will be proportional to $\frac{1}{|\log k|}$. It is convenient to define the return time T_R of this system as an approximation to this such that

$$T_R = \frac{1}{1-|k|}$$

Hence the return time is infinite where $k = 1$ and unity at the rate of fastest damping $k = 0$. T_R may thus be used as a measure of the relative stability of the equilibrium. In general it may be shown that the map of T_R against C_t will be of the form illustrated in Fig. 2.

Figure 2



Accordingly at or near MSY any perturbations to the system will take a very long time to disappear. Furthermore if the parameters of the model are varying randomly then T_R will be inversely proportional to the amount of variability in the stock level and hence inversely proportional to the risk that any strategy will result in the population being reduced to a protected status (Beddington & May 1977). The management implications of this analysis are that an MSY quota is an unfeasible objective in that if there is any noise at all in the environment the stock will be reduced to

status. Furthermore that it is possible to take some proportion of MSY which will greatly reduce the risk of overexploiting the stock. Clearly these considerations apply with much more force where both model and parameters are subject to error. This general analysis in skeletal form will now be made flesh in the next section where the Sei whale model is considered.

The Sei Whale Model

The Sei whale model used in the assessment of quotas in 1976 was

$$N_{t+1} = .94\ (N_t) + N_{t-8}\ (.06 + .0567(1-(\frac{N_{t-8}}{N_o})^{2.39})) - .94\ C_t$$

where N_o is the unexploited stock level.

The equilibrium relationship for this model to determine quotas is

$$.94\ C_t = .0567\ N^*(1-(\frac{N^*}{N_o})^{2.39})$$

which has MSY at $(\frac{N^*}{N_o}) = .6$. Other values for C_t = P x MSY P = .4 — .9 are given in Fig. 3. The relationship between return time and C_t as a proportion of MSY is given in Fig. 4. It can be clearly seen in Fig. 4 that as C_t starts to exceed .8MSY the return time increases at an approximately exponential rate. Accordingly there is a clear problem of compromising between increasing quotas beyond this level and the risk of overexploiting. This risk may be illustrated by using the results of some computer simulations using standard Monte Carlo methods.

The mean time $\bar{t}$ for a particular harvesting strategy to drive the stock below its MSY level decreases with increasing environmental variability (measured as the variance of mortality rate and reproductive rate). Different harvesting strategies produce widely different $\bar{t}$ values varying typically from about 10 years at MSY to 20 years at .9MSY up to 100 years at .8MSY. These simulation results should not be interpreted

as anything more than illustrative of the general message. However the pattern of relative stability given in Fig. 4 qualitatively reflects this marked decrease in the feasibility of the harvesting regimes as MSY is approached.

Taken together with the uncertainties that exist in both model form and parameter estimation there is clearly some justification for moving towards a management strategy aimed at producing a sensible compromise between reduced yield and increased stability.

Effort and Quota Harvesting

The analysis so far has assumed that the harvesting strategy is based upon a quota regulation. An alternative is to consider one based upon effort; this may be modelled by writing EN_t as the total catch in a year and thus rewriting equation (2) as

$$N_{t+1} = F_1(N_t) + F_2(N_{t-k}) - EN_t \qquad (5)$$

Equilibria for this model are obtained in the usual way by writing $N_{t+1} = N_t = N_{t-k} = N^*$ to give

$$EN^* = F_1(N^*) + F_2(N^*) - N^* \qquad (6)$$

and the maximum yield obtained by considering the turning points of (6). In the case of effort regulation there is only one value for $N^* > 0$ which satisfies (6) and this equilibrium is stable. Formal stability analysis of this equilibrium proceeds as in the appendix with the exception that the parameter α is replaced by $\alpha - E$. It can be simply shown that over all ranges of harvesting the return time associated with the effort strategy is shorter than the equivalent quota harvest. This is particularly important near MSY where it becomes extremely large for a quota strategy, but remains relatively small for effort regulation. There are thus considerable advantages to be gained by operating an efficient effort regulation of a fishery. Indeed for some models it may be shown that a

fishery at MSY under effort regulation can be more stable than the unexploited stock.

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Appendix

In General form.

$$N_{t+1} = F_1(N_t) + F_2(N_{t-k}) . - C_t \qquad (2)$$

Equilibria obtained by writing $N_{t+1} = N_t = N_{t-k} = N^*$

$$N^* = F_1(N^*) + F_2(N^*) - C_t . \qquad (3)$$

write $X_t = N_t - N^*$

$$X_{t+1} + N^* = F_1(X_t + N^*) + F_2(X_{t-k} + N^*) - C_t .$$

Expanded F_1 and F_2 by Taylors theorem and ignore 2nd order terms

$$X_{t+1} + N^* = F_1(N^*) + X_t F_1'(N^*) + F_2(N^*) + X_{t-k} F_2'(N^*) - C_t$$

Using Equilibria relationship this simplifies to

$$X_{t+1} = X_t F_1'(N^*) + X_{t-k} F_2'(N^*) .$$

Denote $F_1'(N^*) = \alpha \quad F_2'(N^*) = \beta .$

$$X_{t+1} = \alpha X_t + \beta X_{t-k}$$

Try solution $X_t = A z^t$

$$A z^{t+1} = A\alpha z^t + A\beta z^{t-k}$$

$$A z^{t-k}(z^{k+1} - \alpha z^k - \beta) = 0$$

hence stability is determined by roots of the characteristic equation

$$z^{k+1} - \alpha z^k - \beta = 0$$

writing $T = k+1$

$$z^T - \alpha z^{T-1} - \beta = 0$$

In general we can constrain the roots of the characteristic equation to lie within a circle of radius R centre the origin by writing $z = Re^{i\theta}$

$$R^T e^{i\theta T} - R^{T-1}\alpha e^{i\theta(T-1)} - \beta = 0$$

Expanding

$$R^T(\cos\theta T + i\sin\theta T) - R^{T-1}(\alpha\cos\theta(T-1) + \alpha i\sin\theta(T-1)) - \beta = 0$$

Equate real and imaginary parts.

$$R^{T}\cos\theta T - \alpha R^{T-1}\cos\theta(T-1) - \beta = 0 \qquad (4)$$

$$R^{T}\sin\theta T - \alpha R^{T-1}\sin\theta(T-1) = 0. \qquad (5)$$

One solution for θ is clearly $\theta = 0$

Giving $R^{T} - \alpha R^{T-1} - \beta = 0.$

$$\beta = R^{T} - \alpha R^{T-1}$$

For simple stability ie $R = 1$ the limit is where $\beta = 1-\alpha$.

Note this result is analogous to Levin & May (1976) and Clark (1976).

The lower bound is determined by solving for θ in (5) and substituting back in (4). This will give required values of β.

FIG. 3

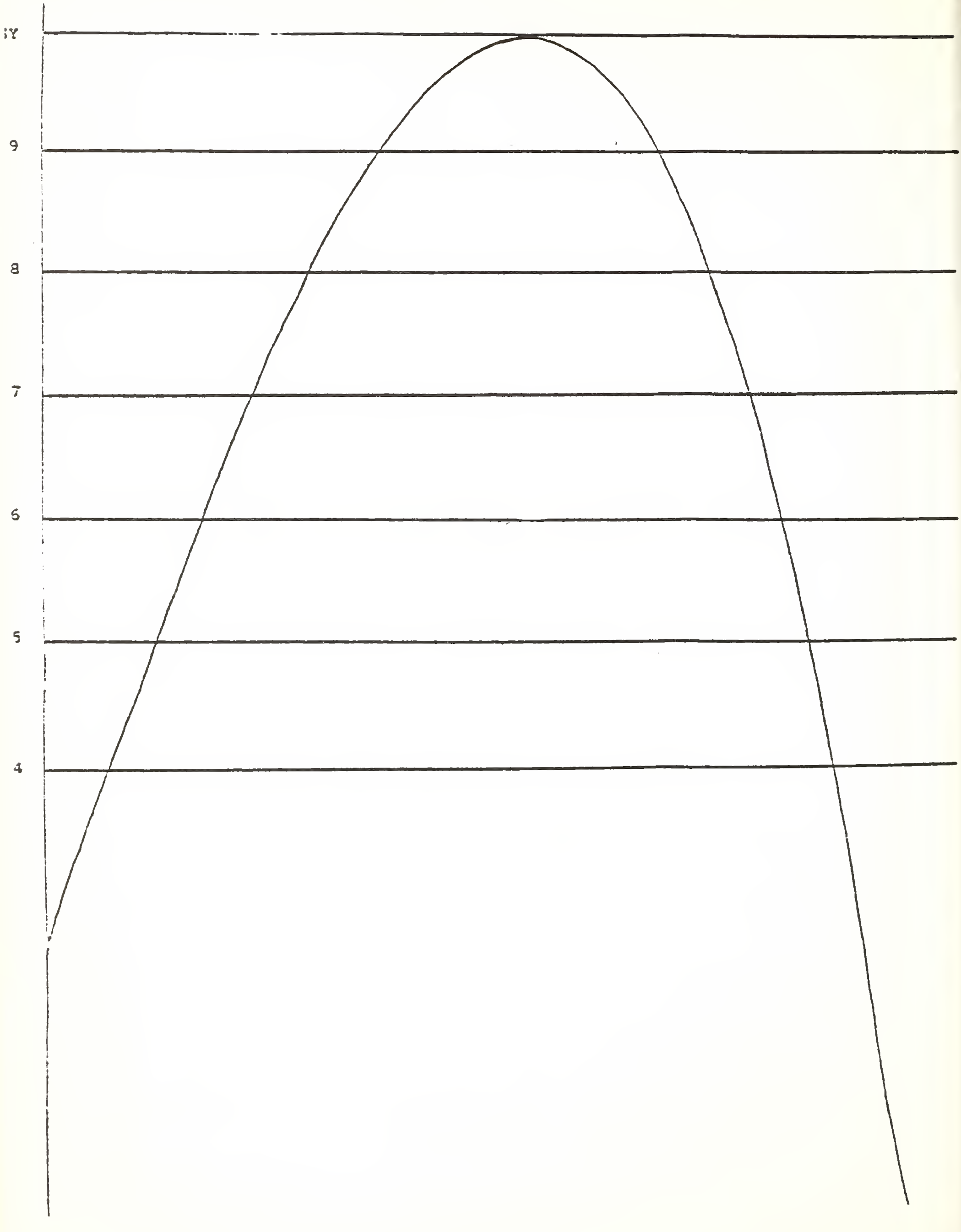
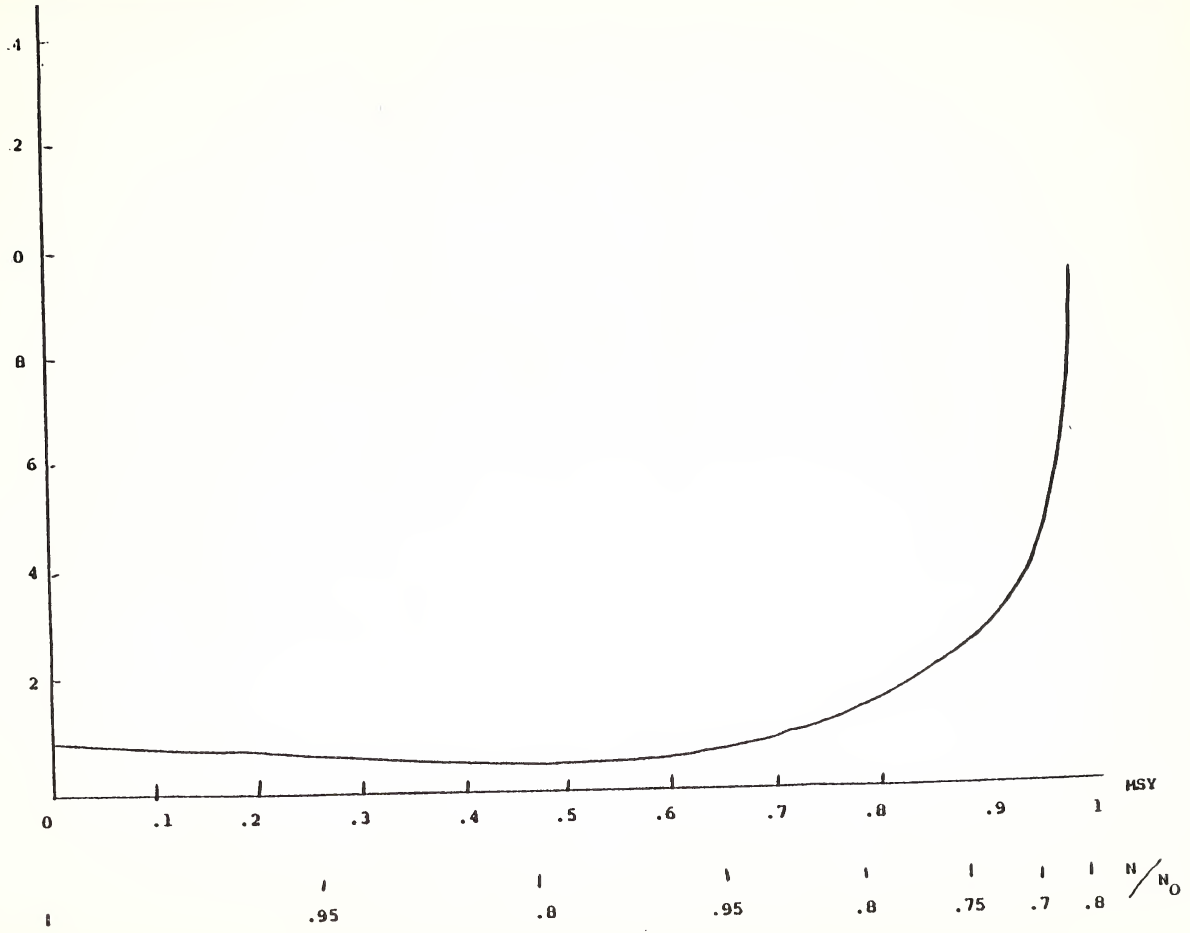


FIG. 4



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RECOMMENDED BOWHEAD RESEARCH PROGRAM

In June 1977, the International Whaling Commission (IWC), acting on the recommendation of its Scientific Committee, voted (16 to 0; U.S. abstaining) to delete from its schedule of Regulations the exemption for the subsistence killing of bowhead whales. If the United States does not object to the IWC action, subsistence hunting of bowhead whales will be prohibited after the fall 1977 hunt. This matter probably will be re-examined at the 30th Annual Meeting of the IWC (June 1978).

In view of the possible impact that unregulated subsistence hunting may be having on the western Arctic population of bowhead whales, and the likely adverse impact that a moratorium on whaling would have on Eskimo whaling communities, there is a critical need for better information concerning the status of the stock. There also is a need to develop regulations, techniques, and equipment which will reduce, to acceptable levels, the number of whales struck and lost if subsistence hunting is conducted.

Research Objectives

The purpose of this research program is to provide better estimates of the current and pre-exploitation levels of abundance and productivity of the Western Arctic population of bowhead whales. A secondary objective of the research program is to determine how the number of whales struck and lost in the course of subsistence hunting might be reduced.

Information Needs

Information on the current abundance and productivity of bowhead whales in the Western Arctic is inadequate, by itself, to serve as a reliable basis for judgments concerning the number of whales which might be taken without adversely

affecting the population. For this purpose, the status of the population must also be determined.

Population status refers to the relative abundance of the population with respect to the carrying capacity of its habitat (carrying capacity is the number of whales that would exist under natural equilibrium conditions -- i.e., in the absence of human influence). Since the "state-of-the-art" is such that carrying capacity cannot be predicted from an examination of environmental parameters, the pre-exploitation level of abundance generally is used as a measure of the habitat's carrying capacity. Therefore, to determine what might be an acceptable level of subsistence harvest requires answers to the following questions:

1. What is the present size and productivity of the bowhead whale population in the Western Arctic?

2. What was the size of the population prior to the beginning of commercial exploitation?

If the answers to the questions noted above indicate that some level of harvest could be permitted without adversely affecting the existing population, only part of the IWC's concern will have been resolved. Something must be done to reduce the number of whales struck and lost; that is, more efficient equipment and hunting practices must be developed and used in the course of any hunting activities that are conducted. To develop hunting practices and regulations that reduce, to acceptable levels, the number of whales struck and lost will require a comprehensive knowledge of whalers' attitudes, methods, and equipment.

Assumption

If it reasonably can be shown that some number of bowhead whales could be taken annually without significantly affecting the population's probability of extinction or its ability to recover from commercial exploitation which ended in the early 1900's, and if an effective management program can be developed to limit the harvest to that level and to reduce loss rates to acceptable levels, the IWC may reverse its action deleting the provision which allowed for subsistence hunting of bowhead whales from its schedule of Regulations.

Methods

The program outlined below is designed to provide the maximum amount of data in the shortest time possible. Where possible, studies are planned to be concluded before the next IWC meeting.

Aerial Surveys

Aerial surveys, if properly designed and carried out, are the quickest and most cost-effective way to estimate abundance. Designing and carrying out surveys that provide reliable abundance estimates, at minimal cost, however, are not simple tasks. Among other things, the species' distribution pattern (range) and the probability of sighting an animal, at different times of the year and under different environmental conditions, must be determined accurately before actual counts can be extrapolated to provide a population estimate.

If ice conditions, weather conditions and aircraft performance are satisfactory, the required density and distributional data should be acquired in the first year (FY 78) and full-scale surveys may not be needed in subsequent years. However, as noted above, there are many variables which could affect census results and, consequently, the budget includes funds for a major survey effort in the spring and summer of 1979, as well as smaller monitoring efforts at three year regular intervals.

September-October 1977: Past attempts to use aerial surveys to estimate the abundance of bowhead whales have had limited success, primarily because there is inadequate behavioral and distributional information to properly design the surveys. Therefore, the purpose of this survey is to evaluate census methodology as well as provide an estimate of abundance.1/

1/ Survey aircraft should have two or more engines, an unobstructed view forward and downward, and a navigational system with a position error no greater than 1/10th of a nautical mile. Two estimation schemes would be used concurrently, one based on a fixed strip width and the other using all observations and line transect theory.

Available distributional data suggests that whales begin moving out of the Beaufort and Chukchi Seas in late August and early September. At this time of year, therefore, it is expected that the greatest numbers of whales will be found along the ice edge, or in the open water of the Chukchi and northern Bering Seas. It is proposed, therefore, to carry out a systematic survey of these areas to attempt to locate concentrations of whales. The results of the survey would help identify optimal census design and effort, and would be available prior to the 1978 IWC meeting.

The estimated cost ($55,250) includes 100 hours flying time, 75 man-days of observer time (at $150 per day) and $1,500 for data processing.2/

Survey Planning Meeting: The results of the fall '77 survey and the preliminary results of the logbook analysis (see page 8) should be available by early March 1978. A group of experts, knowledgeable in survey design, would be convened at that time, to design and plan surveys to be carried out in the spring, summer, and fall of 1978. The estimated cost of the meeting, including consultation fees for outside experts, is $5,000.

April-June 1978: Although the wintering grounds of the Western Arctic population of bowhead whales are unknown, it is known that whales begin moving past St. Lawrence Island in late March and early April. By early June, an unknown portion of the population has moved past Barrow to the Beaufort Sea. An aerial survey should be used to estimate the number of whales moving along the retreating ice edge and through inshore and offshore leads.

Cost will be dependent upon the survey plan developed by the planning group. Assuming 150 hours flying time and two observers, the best possible estimate at this time is $87,500.

July-August 1978: This survey, part of which would be carried out in cooperation with Canadian scientists, should concentrate on the open water areas of the Chukchi and Beaufort Seas. The best cost estimate at this time is $87,500.

2/ Availability and cost of suitable aircraft have not been determined precisely. Charter costs likely will be between $350 and $500 per hour -- mid-point equals $425 per hour. Personnel requirements assume using two observers, at least for the first survey (Sept. - Oct.). Depending on initial results and the kind of aircraft finally chosen, four or more observers may be needed.

September-October 1978: This survey would be an improved version of the survey carried out in September-October 1977. It would help identify the between-year variation in density and distribution patterns and, along with the surveys discussed above, would provide a basis for determining whether additional surveys would be necessary or desirable. The estimated cost is $55,250.

Icebreaker Survey (April-May 1978)

In view of the fact that bowhead whales migrate through open leads in the Arctic ice pack, an icebreaker is needed for long-term studies of behavior and movements. Aircraft, while useful for collecting information on abundance, cannot be used efficiently to track or to observe the behavior of individual whales. Since the whales begin arriving at St. Lawrence Island in late March and early April, it is proposed to begin icebreaker studies on 1 April 1977. The ship, its helicopters, and small boats would be used to observe, count, and mark whales found in the vicinity of St. Lawrence Island during the period 1-15 April. Acoustic recordings would be made and analyzed to determine whether it might be feasible to track and/or count whales by monitoring vocalizations. Radio-tagging studies would be conducted to determine if it might be feasible to use available equipment to track whales moving through pack ice.3/

In mid-April or earlier, depending upon ice conditions, the ship would move northward, past Cape Prince of Wales and Point Hope, arriving in the vicinity of Barrow in late May. Helicopter surveys would be carried out on a daily basis, weather permitting, to determine the numbers and age-sex composition of the migrating whales. Small boats and helicopters would be used to mark as many whales as possible. Photographs of whales would be taken and evaluated to determine if they might be useful for identifying individuals.

The estimated cost of the icebreaker program, exclusive of ship costs, is $50,000. All of the study objectives may not be achieved by a single cruise and it probably will be necessary to replicate all or part of the icebreaker studies in the spring of 1979. Since the NMFS does not have sufficient personnel or in-house expertise to carry out these studies, part or all of them would be contracted to persons outside the Service.

3/ Conduct of radio-tagging studies would be dependent upon a thorough evaluation of existing technology and a determination that the whales would not be adversely affected by the tags.

Data from the cruise, although it would not be fully analyzed, would be available prior to the 1978 meeting of the IWC.

Tagging Studies

Mark-resighting studies can be used to provide information on abundance, movements, and survival. At present, however, a proven method of marking bowhead whales is not available and tag development-evaluation studies are needed before a full-scale marking program can be begun.

Taking into account work being done elsewhere, $25,000 is the best possible cost estimate to develop and evaluate a suitable tag. Development work probably would be carried out under a contract to the Bay St. Louis Engineering Laboratory (NMFS). Field evaluation would be carried out by NMFS personnel or contracted to an outside investigator.

Assuming that a suitable tag could be developed in time, Eskimo whaling crews would be hired to mark animals during the spring migration (mid-April to early June). Four crews of six each would be required for a period of four to six weeks. Two crews would be assigned to work southeast of Point Hope and the remaining two southwest of Barrow. A scientist/observer would be assigned to each whaling crew. Estimated cost, $75,000.

Counting Stations

To provide better information on the spring migration, counting stations would be established at Point Hope, Point Barrow, Cape Lisburne, and at Little Diomede Island. A five-man team, including at least one Eskimo advisor, would be assigned to each station. Each team, weather permitting, would make round-the-clock observations, noting the number of marked and unmarked whales passing the observation point. Acoustic recordings would be made to determine if vocalization patterns can be correlated with the numbers or behaviors of whales that are observed. A helicopter or fixed wing aircraft would be assigned to the Point Hope and Barrow team, and used to determine the relative numbers of whales moving through leads which cannot be observed from the counting stations. Estimated cost, $105,000 per year.4/

4/ Cost estimate includes 60 hours of aircraft time at $350 per hour.

Harvest Monitoring

Harvest monitoring, of course, would be dependent upon the existence of a hunt and the cooperation of the Eskimos. One monitoring team, consisting of two biologists and an Eskimo para-biologist, would monitor the fall 1977 hunt from Barrow. Spring hunts, if they occur, would be monitored by two teams each at Barrow and Point Hope, and one team on St. Lawrence Island. Each team would sex, measure, and collect ear plugs and reproductive materials from whales taken during the hunt. They also would try to develop better information on the numbers of whales struck but lost. One biologist would travel to each of the other villages (Wales, Kivalina, and Wainwright) to determine how many whales were taken at these villages, and to collect biological specimens. Estimated cost, including analysis of biological specimens, is $120,000 per year.

Acoustic-Behavior Studies

Better information on diving times and travel speeds, at different times of the year and under different environmental conditions, is needed to design more effective aerial surveys and to evaluate data collected from counting stations. Similarly, better information on behavior and vocalization characteristics is needed to judge whether it might be possible to use acoustic recording stations to monitor the movements and relative abundance of the whales. If, for example, frequency of vocalization is found to be highly correlated with numbers of whales, it might be possible to establish listening posts in the Bering Strait, and/or other strategic areas, to monitor the relative numbers of whales moving past the stations.

In August-September, a concentration of bowhead whales occurs near Cape Simpson, east of Barrow. This area may be ideal for carrying out behavioral and acoustic studies and preliminary studies are planned for this fall. Among other things, the preliminary studies will include: observation and recording of dive times; limited aerial surveys to estimate the size of the concentration; and underwater recordings to determine if the whales are calling and, if so, whether the calls can be correlated with the behavior and/or abundance of the whales. If the preliminary study is fruitful, the project would be expanded in FY 78 to include ship-based studies.

Preliminary acoustic studies would require purchase of three sets of hydrophones and recorders for use at Cape Simpson and the counting stations at Point Hope and Barrow (estimated cost -- $7,500). Vessel charter for the expanded

studies in FY 78 would be about $20,000 ($2,000 per day for 10 days). Follow-up acoustic studies, if warranted on the basis of preliminary results, probably would cost about $50,000 for prototype development and evaluation (FY 79). The cost of establishing and operating an acoustic monitoring system will be dependent upon equipment and personnel requirements and, consequently, no cost estimate has been provided.

Radio-Tagging Studies

If preliminary radio-tagging studies indicate good tag retention characteristics and that the tags are safe, up to 25 adult whales would be tagged with remotely implantable transmitters to monitor activity patterns and movements. Implantation of tags would be done at the tagging stations and monitoring would primarily be from the aircraft assigned to the counting stations. Movement and distribution data thus acquired would aid immensely in the development of cost-effective aerial surveys. Estimated cost is $25,000.

Biological Studies

There are a number of collections of baleen plates, ear plugs, and reproductive materials from bowhead whales. Although these materials can provide useful information on age and reproductive condition of whales that have been killed, some of them have not been fully analyzed. If the necessary analysis cannot be carried out quickly by in-house personnel, some of the work should be contracted out -- estimated cost. $15,000.

Whale Logbook Study

Whalers' logbooks contain information that can be extracted and analyzed to provide better estimates of abundance and production prior to and at the conclusion of commercial whaling. This information, coupled with more reliable estimates of present abundance and production, would permit a more accurate determination of the present status of the stock. Analysis of historic catch records also would provide distributional data which would be useful for designing more cost-effective aerial surveys. Therefore, a thorough analysis of all existing catch records should be undertaken as soon as possible.

If the study is under way by 1 October 1977, preliminary results should be available for the aerial survey "design" meeting planned for March 1978, and for the 30th annual meeting

of the IWC. The estimated cost of the project is $100,000.

Management Options

Failure to kill and recover a whale that is struck can be attributed to poor technique, malfunctioning equipment, or some combination of both ("luck"). The apparent increase in the numbers of animals struck but lost in recent years seems to be correlated with increasing numbers of whaling crews -- suggesting inexperience -- and failure to "strike" the whale before using the shoulder gun. Prior to the June 1978 meeting of the IWC, a thorough analysis of whaling practices and equipment should be carried out to determine, as possible, the cause of and possible solution to the increase in the number of animals struck but lost. Alternative methods of regulating and enforcing a moratorium, or limited take, should be evaluated to determine what alternatives afford the greatest protection to the whale population, with minimal impact on the culture, economy, and health of the Eskimo whaling communities.

Eskimos would play a major role in identifying and implementing solutions to the problem. Expert whaling captains would be involved in identifying the probable causes of losses and developing gear and practices to be employed to reduce loss, limit the number, size, sex, or location of whales that may be taken, as appropriate, and allocate them among the several whaling villages. Such a detailed system of controls would be available for review by the IWC at its next meeting and would be implemented to apply to any whaling activities that may be conducted after the fall 1977 hunt. Funds would be made available for an investigating team and whaling captains to meet and obtain such outside consultation as may be necessary. Estimated cost is $35,000. Funds would also be made available to meet periodically to review the results of the management program and formulate additional recommendations concerning any subsistence whaling that is conducted. Estimated cost is $15,000 per year.

Expected Results

If the aforementioned studies are carried out as proposed, it is reasonable to expect that by June 1978, we will have a much better understanding of the current status of the bowhead whale population in the Western Arctic. There is no way to tell whether the studies would prove or disprove the concern that Eskimo subsistence hunting may be significantly increasing the probability of extinction of the Western Arctic population

of bowhead whales. However, the fact that the population has sustained a continued subsistence hunt since the termination of commercial whaling in 1910 suggests strongly that some limited take might be possible while still permitting the population to increase. Therefore, if the studies are carried out, it seems likely that the resulting data would support an argument for at least a limited hunt. If they are not carried out, and if an effective management program is not developed, the status quo will be maintained and it is likely that the IWC's Scientific Committee will arrive again at the conclusion that subsistence hunting poses an unacceptable threat to the existence of the bowhead whale population in the Western Arctic.

In conclusion, conduct of the research program listed above will not guarantee reversal of the IWC action. Conduct of anything less than the proposed program, however, will almost certainly ensure that the problem will not be resolved.

BUDGET SUMMARY

	FY					
	77 1/	78	79	80	81	82
Aerial Surveys						
Fall	55.25	55.25	--	--	--	--
Spring	--	87.5	87.5	--	100	--
Summer	--	87.5	87.5	--	--	--
Survey Planning Meeting	--	5	--	--	5	--
Icebreaker Survey 2/	--	50	50	--	--	--
Tag Development & Evaluation	--	25	--	--	--	--
Tagging Studies	--	75	75	75	--	--
Counting Stations	--	105 3/	105 3/	80	80	80
Harvest Monitoring 4/	25	120	120	120	120	120
Acoustic-Behavior Studies	25	50	50	?	?	?
Radio-Tagging Studies	--	25	25	25	--	--
Biological Studies	15	--	--	--	--	--
Logbook Study	--	100	--	--	--	--
Management Options	--	35	15	15	15	15
	120.25	820.25	615	315	320	215

1/ Includes only studies to be carried out in the fall of 1977.

2/ Does not include cost of operating the icebreaker or its helicopters.

3/ Includes 60 hours of aircraft charter, either helicopter or fixed wing.

4/ This budget item would be deleted in any year that a subsistence take does not occur.

? The desirability of further studies cannot be identified on the basis of currently available information.

PROPOSED

SCOPE OF WORK

FOR AN

OCEAN INFORMATION SYSTEM TO IDENTIFY AND KEEP TRACK OF THE BOWHEAD WHALE TO PERMIT SPECIE MANAGEMENT

AUGUST 1977

Prepared for

U.S. Department of Interior

by

North Slope Borough, Alaska
Arctic Slope Regional Corporation
Barrow Whalers Association

SYNOPSIS

This proposal describes a sophisticated information gathering and data interpretation system which will permit the application of available information systems techniques to the challenge of learning the size, extent and migratory habits of the Bowhead whale. The Bowhead has a special significance to the Inuit (Eskimo) residents of the coast of the Arctic Ocean. The Inuit have taken the Bowhead for thousands of years for sustenance. Their association with this whale existed long before the advent of the European culture on the North American continent. Today, this whale is felt by some to be an endangered species. This endangered condition was not caused by the Inuit. It is not clear that the Bowhead is, in fact, a declining species. Whatever the actual state of the specie; the threat to it has been, and is likely to be, from advanced technology or its associated artifact, pollution.

This program will provide an advanced (but available) technology approach to determining the true nature and habits of the Bowhead. The system will use elements of space and airborne remote sensing technology; undersea marine data gathering to yield specie acoustic and other signatures; and provide for passive and occasionally active tracking over significant geographic areas in the Beaufort, Chukchi and Bering Seas and into the Pacific Ocean.

As a measure of the commitment of the Inuit to this program

there will be cost sharing with the Federal Government. The people of the North Slope Borough have agreed to provide $ ______ as an initial increment of this cost sharing. This is the Inuit "Investment in the Bowhead Whale" in lieu of a dividend distribution to stockholders from the Arctic Slope Regional Corporation for 1976. Should the full project be undertaken, the Inuit plan to support it with more than $500,000 in labor services.

The customers for the service that will be provided by this advanced ocean information system are:

- The various government agencies with primary and supporting needs for data for rational specie management of marine mammals in general.
- The Inuit for continued access to this historically and socially significant natural resource at periodic intervals.
- Foreign governments through protocols, direct data exchange and other means to facilitate their policing of their whaling ships to reduce predatory killing of this particular specie, the Bowhead whale.

If part of the role of national governments it to manage resources for the common good, the question can be asked: "How can you manage something if you don't know what it is?" The application of available information systems technology to this mission of learning more about the Bowhead whale is part of finding out "...what it is."

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APPENDIX A. Data Collection Techniques

1.0 INTRODUCTION

This section provides a brief background and historical perspective on the Bowhead whale, the Inuit culture, and the Inuit hunting techniques. It provides the frame of reference for the proposed information system in terms of the governmental "whale management" status, and it discusses certain political aspects of the current "whale management" condition.

1.1 SPECIE BACKGROUND AND HISTORY

1.1.1 The Basic Population

The Bowhead or Greenland Right Whale (Balaena Mysticetus) is the bulkiest of the great whales. It is closely related morphologically to the Right Whale but inhabits the Arctic Regions further North. (Scammon, 1874) The Bowhead specie has been classified into four distinct "stocks" based on the specie's migrational patterns. (Scammon, 1874; Tomilin, 1967; Rice and Scheffer, 1968) The first stock is located in the Greenland sea. Extremely active commercial whaling for a three hundred year period from the 17th to 20th century reduced this stock to marginal status. (Vibes, 1967; Jenkins, 1921) Only a few Bowhead whales are sighted each year in the Greenland-Spitzbergen area. (Vibes, 1967; Allen 1976) Two more heavily depleted stocks are located in the Baffin Sea (Tomilin, 1967) and the Sea of Okhotsk (Berzin & Kuzmin, 1966) The fourth stock migrates between the Chukchi Sea - Beaufort Sea and the Bering Sea. Most marine mammal specialists agree this fourth stock is the most plentiful. (Mitchell, 1975) This surveillance proposal deals with the Bowhead contained in the fourth stock.

1.1.2 Biology and Population of the Bowhead

The Bowhead derives its name from the large size and shape of its head, which comprises one-third of its total body length. The Bowhead can use its head on occasion to smash up through the ice to breathe. (Scammon, 1874) The whale is found close to the pack ice in open leads but will move under the ice when danger is present. (Scammon, 1874)

Very little is known about the behavior or biology of the Bowhead. This is partly due to the extreme environmental conditions under which they live (Scheffer, 1976) and lack of advanced technology being employed to get the needed data. Data on the fertility rate, (Tomlin, 1967) gestation rate, (Gray 1940) mortality rate, effect of pollution on the specie, (Vibes, 1967; Report of the U.N. Advisory Commission on Marine Mammal Research, 1976) effect of offshore oil exploration, (U.N. 1976) and the reduction of worldwide krill(U.N. 1976) are conspicuous by their absence. To quote,

> "Ecological Problems: The north-slope oil project might alter the inshore southward migration should full steamer and barge traffic increase to force the whales farther offshore." (Federal Register, Report of the Secretary, p. 39010)

The Bowhead contains a thick layer of blubber and large baleens, used by the whale to strain phytoplankton, or krill from the water. (Scheffer,1976) During the late 1800's, these whales were hunted extensively by commercial whalers because of the large quantities of oil and whalebone they contained. (Scammon,1874) In 1848, the Bering Sea-Chukchi Sea stock was discovered by

Captain Royce, who assembled a fleet of 154 ships to hunt them in 1849. (Scammon,1874) The whales were hunted intensively until the 1860's when the prices began to decline. The number of whales taken fell around 1870. (Clark 1887) In 1915 the last reported commercial whaling of Bowhead occured by the steamer *Herman* and the whaling schooner *Belvedere*. (Report by Marquette for NOAA, 1977)

1.1.3 Legal Status of the Bowhead

The Bowhead has been regulated by the International Whaling Commission since 1947 and protected from commercial fishing. The Marine Mammals Protection Act of 1972 and the Endangered Species Act of 1973 reinforced the ban. Aboriginal subsistence hunting is protected in these three provisions.

1.1.4 The State of Knowledge on the Bowhead

The exact number of Bowhead whales off Alaskan waters is not known; or, whether the specie is recovering from previous over-whaling. Recent attempts at counting the population were made by Braham and Krogman for NOAA (may 1977) during the migration of 1976. Some aerial surveillance was used as well as land sightings from two camps located off Point Barrow. 357 whales were sighted using this method. The Bowhead follows a migration pattern that passes through the Bering Straits in early spring. When they reach open water they disperse; besides the Beaufort Sea group, some go to waters off Northern Siberia, and some move into more open waters in the Chukchi Sea.

To Quote the NOAA study:

> "The spring migration route east of Barrow is poorly defined. Also, it is unclear what percentage of the total population moves past Barrow. Perhaps some animals remain in the northeastern Chukchi Sea throughout the summer." (Braham and Krogman for NOAA, 1977)

No attempts were made in the Braham and Krogman study to incorporate the Siberian and Chukchi Sea dispersion data into their analysis.

The state of official knowledge about the Bowhead is shown in the "Report of the Secretary" on the status of Marine Mammals (Federal Register, August 1, 1977)

> "The Bowhead whale population of Canada and the Bering, Chukchi, and East Siberian Seas appear to be increasing (Monsfield, 1971; Burns, para. Comm)" p.39010

The current reports on the Bowhead whale population and behavior patterns reflect how little is actually known about the

specie. Further investigation and surveys are needed. Only surveys that employ advanced technology can supply the scientific community with biological, population and mortality data that is crucial to the formulation of a sound policy for the stability and recovery of the Bowhead specie.

1.2 INUIT ENVIRONMENT AND CULTURE

1.2.1 The Cultural Aspect

The term "Eskimo" embraces a group of cultural forms with considerable diversity between them. But the term "Eskimo" is useful to describe a people oriented around a marine food source economy. (Oswalt,1967) The culture, broadly defined, is at least 4000 years old, since a highly developed whale hunting society has been identified since 1800 B.C. (Oswalt, 1967) Although the Bowhead specialization is specific to the Inuit (Tareumiut), the focus of Eskimo culture is on marine food sources and in general and marine mammal hunting specifically. Outside observers have noted the social and cultural importance of the Bowhead to the Inuit.

For example, Oswalt says,

> "A man's most important social and economic bone beyond his household was with an umialik, an individual who not only owned a large skin boat but also led a whaling crew."
>
> (Oswalt, 1967)

J.W. Vanstone noted,

> "Weekly movies, a popular event at Point Hope, for the first time were not shown during the whaling season so that the temptation to leave the whaling camps would be lessened."
>
> (Vanstone, 1962)

Or consider Spencer,

> "The emphasis on whaling among the coastal peoples places this institution at the keystone of the ceremonial activities."
>
> (Spencer, 1959)

An Inuit declared,

> "Without the whale, there is no Eskimo."
>
> (Interview with C. Edwardsen, Jr., (Etok),1977)

1.2.2 The Economic Aspect

The capital accumulation associated with a whaling expedition involves the equipment and the subsistence support for the crew. The coastal Eskimo developed a "capitalist" economic system which has analogs in the commercial trading ventures of 16th and 17th century Europe. The original financial constraints on forming whaling crews have lessened with the influx of oil and development money but the socio-economic status of the umialik is still significant (Vanstone, 1962)

The whale as an economic asset had so much influence on the Inuit that the entire society, including trade, revolved around the whale, and the whale hunter. From a pure commodity flow point of view, the whale no longer is so vital. (Vanstone,1962) However, the dependence of the Eskimo upon lower 48 goods leaves open the question as to what happens to the society when the Western industrial system loses interest in the Eskimo and the mineral assets under his lands. The most important feature of the whale is that is moves of its own accord to the Eskimo. The seasonal exploitation of this asset by the Eskimo has made possible a healthy, interesting culture which is self-sufficient within the traditional communication and trading networks of the Arctic.

1.3 INUIT HUNTING TECHNIQUES

The Inuit hunting technology has shown little sign of change when viewed in comparison with the archeological remains (c.1800 B.C.) at Cape Krusenstern. (Oswalt,1967) The hand-held harpoon and lances have been replaced by the harpoon gun and the darting gun with exploding bombs. These make the kill easier but do not change the methodology of whale hunting significantly. The simplest explanation for the cultural continuation of hunting methods is that they are effective when employed by skilled hunters.

The Eskimo hunt whales in skin boats called umiaks with the captain, the umialik, being a man that has accumulated enough wealth to own a boat and support the crew for the entire season. The whaling crew consists of a harpooner, the umialik, and usually 4 to 6 other crewmen. Once a whale is sighted from the shore the crew silently paddles out very close to the whale to get a good shot. The harpooner then uses the harpoon gun for the initial strike. After a whale is struck they sometimes sound, a very dangerous time, for the whale can surface so near the umiat to tip it over. If the whale retreats under the ever present sea ice and manages to pull free of the harpoon, the whale can be lost.

Once the whale is harpooned, the Inuit tries to use the shoulder held darting gun to kill the whale. Other crews in the area will come to assist the first crew in killing the whale and bringing it to shore. Cooperation and teamwork among the whaling crews is vital to a successful hunt, and in butchering the whale

is shared among all who participated and to a lesser extent the entire village.

In recent years the number of umialiks has increased. Men with access to the lower 48 cash economy become wealthy enough to buy the necessary equipment. This cash influx circumvents the traditional route of attaining umialik status and, consequently, much of the traditional lore and skill. This circumvention has had the effect of lowering the skill and experience of the crews and increasing the number of whales struck and lost. There have also been reports of the darting guns without harpoon lines being used before the harpoon.

The Inuit view this problem as a serious threat to the traditions of whaling and to the Bowhead themselves and internal adjustment at the native community level is being made. Note that since the Inuit hunt whales for subsistence and take only the number of whales necessary to support the village, modern technology could improve the kill-lost ratio. For instance, tracking devices could be installed on the harpoons which would decrease the struck and lost ratio and probably the total killed.

Whale hunting by the Inuit is a vital economic act. But also the skill, courage, forebearance, and executive ability required of the hunt, have merged into and evolved with the general social structure.

1.4 CURRENT SPECIE MANAGEMENT TECHNIQUE

1.4.1 Background

"Specie Management" is a Western cultural-economic artifact when applied to the Bowhead whale. The Eskimo, having lived in balance with the Arctic and Arctic Slope for 7000 years, does not "manage" the Bowhead, he lives with the specie - as he does with the seal, walrus, eider duck, caribou, etc.

Had there never been commercial whaling, oil slicks, and industrial pollution, the whale and the Eskimo would not need "management" - any more than the people of the Southern latitudes needed to manage air before idustrialization.

Nevertheless there has been commercial whaling and the Bowhead is depleted from the original stocks. There are already some off-shore industrial operations on the North Slope of Alaska and the breeding grounds may be affected. There has been industrial pollution of the Pacific and the krill supply may be affected. In shore more than one set of Western cultural artifacts has already been applied to the Bowhead with adverse effects on the specie. It appears necessary to Western culture to follow up the commercial whaling and pollution with another cultural artifact, the hopefully benign, "specie management".

1.4.2 Concept

Specie management works from the thesis that a healthy specie has a natural rate of growth given a suitable ecological niche and margin in the life support parameters. If individuals are to be killed for commercial, sport or crowding reasons, there is some fraction of the population which can be taken indefinitely within the constraints of the local ecosystem. This fraction is the "optimal yield".

Variables which affect optimal yield are: number of females in the fertile age range, fertility rate, live and birth rate, infant mortality, loss to natural hazards, disease, predators and impact of the specie on the ecology. Given a basic "capture" requirement, another variable, captured/presumed killed rate is important.

To illustrate: if a population of 1000 has a gross fertility rate of 150 per 1000 and the survival to maturity rate is 50%, the population could sustain human·kills to a level of 75 per year (assuming a balanced male/female kill ratio) without depletion. If the human capture/presumed killed ratio is 80% then 60 individual animals per year could be taken.

1.4.3 Practice

Management of the Bowhead has, until recently, been simply protection against legal commercial whaling. Increasing environmental concern and rising interest by the general public in the whale have focused interest in some form of explicit management procedure. Since virtually nothing is known about the optimal yield of the Bowhead stock, the policy of choice by the I.W.C. has been complete prohibition of any whaling, including subsistence hunting by the Eskimo.

Encroachment on the aboriginal rights of the Eskimo began at the 28th Session of the International Whaling Commission and has moved toward prohibition since then.

1.4.4 Implication

Prima~~e~~ Facie, elimination of Eskimo hunting would remove the last serious source of predation and the Bowhead stock should recover. Aside from the devastating impact such a policy would have on the Inuit culture, the pollution/development effects upon the whale population would remain unknown. Certainly prohibition of hunting has not been sufficient for expansion of the stock of California Condors and to move blindly into policy of complete hunting prohibition of the whale may have a similar lack of efficiency on improving the whale stock.

1.4.5 Summary

Survival of the Bowhead whale as a specie serves an ethical or aesthetic purpose to the general public. On the other hand, the Bowhead specie is a critical social, cultural, economic keystone to the Inuit Eskimo. The urgency of the issue is very high to both groups but the simplistic specie management approach of the I.W.C. is not satisfactory to the Inuit - nor should it be to the general public.

A truly scientific attitude about the Bowhead whale should be to examine the specie condition explicitly and in depth. When the facts are available, a rational specie management policy can be developed. Without such facts, any government policy of "whale management" is likely to be wrong and counterproductive.

1.5 POLITICAL CONSIDERATIONS

When oil was discovered at Prudhoe Bay the Arctic regions of Alaska became immediately important for its wealth of resources. With the advent of the energy crisis, the lower 48 viewed Alaska as an asset in oil diplomacy. With the first shipment of Prudhoe oil this year and more oil field exploration taking place in the Arctic this vast domestic oil source is becoming a useful reality.

However, before this source of energy could be tapped political considerations had to be met; namely, the claims the Eskimoes has on their lands. This consideration was by no means trivial and took 2-1/2 years of intensive study and negotiation to resolve the Alaska native claims settlement. This settlement was fair and just and one in which the wishes of all sides were met and dealt with. The Eskimoes were granted a land and monetary settlement as full citizens of the U.S. The Alaskan Natives Claims Settlement Act P.L. 92-203 also reaffirmed the U.S. belief in human rights and self-determination for all its peoples.

In 1977 the Inuit are faced with another threat to their rights and their self-determination and the analogies between the two cannot be overlooked. In both cases the lower 48 and the world had a problem which it perceived must be dealt with. The solution to the first problem could have been dealt with in a manner far less equitable to the Eskimo. But our government and the Inuit were not about to allow that type of solution to occur. For it is our belief as Americans that denial of rights to one group of citizens undermines the rights of all.

The denial of the subsistence hunting of the Bowhead whale would and does pose a dire threat to the rights of the Eskimo. This threat is compounded by the fact that it is not only certain interest groups in the U.S. that are clammoring for full protection of the Bowhead, but it is also a world body, the International Whaling Commission. Since its inception in 1947 the U.S. government's commitment to this organization has increased its power and strengthened its role in protecting and studying the worldwide whale population.

At first glance the U.S. would appear to be in a dilemma; caught between its interest in protecting and furthering the good works of the I.W.C. or protecting the subsistence and human rights of the Eskimo. However this is not the case for the basic philosophy of both groups is the preservation of a healthy Bowhead whale population. Both groups also agree that scientific research on the specie is the main way to attain this goal.

It is for that reason that the Inuit are putting forth this proposal and assuming partial financial responsibility. For they realize that only through a study using sophisticated technologically advanced methods can they help to insure the stability of their whale - the Bowhead.

2. PROJECT REQUIREMENTS

It is essential to establish the objectives of a project before entering into it. The objectives of this project may appear slightly different to each of the interested parties. Nevertheless, a synthesis of objectives, and hence the project requirements, can be derived which is responsive to the needs of all the parties.

Certain basic truths are acknowledged by all:

- No one wants the national government to make decisions which are not supported by facts.
- No one wants the Bowhead whale specie to become extinct.
- No one wants the cultural continuity of the Arctic-adapted Inuit to be destroyed.

Embodied in these truths are the project requirements. They are discussed below.

2.1 IMPROVED DATA BASE FOR DECISIONMAKING

One of the purposes of organized government is to gather data to help decisionmaking by members of society and by government, a parable is offered.

When a U.S. farmer listens to an evening weather report, prepared by an agency of government, before deciding to plant seed on the following day he has actually gone through a number of evolutionary cultural steps. He has delegated part of the data gathering about the probable state of the weather on the morrow. He agrees to have government gather and disseminate the data, and he pays a fee (taxes) to permit this to be done on the collective level. He does this rather than trusting to his own nose to predict the weather.

For many years the U.S. Weather Service did its best, at a given level of technology, to provide predictive weather forecasts. Many farmers were unimpressed by the accuracy of the forecast. Unfortunately, the farmer could not cease paying for the service because once levied, taxes are paid whether or not the service is provided, or useful.

In the 1960's, the predictive capability of the U.S. Weather Service started to dramatically improve. This occurred because of a technology borrowed from a parallel government program, the NASA space program. Weather satellites were placed in earth orbit. The view of the whole earth provided by sensors on these satellites, and the instant communication back to earth of this information, has transformed weather forecasting from an art to a science. Now the farmer would be a fool not to pay close attention to the weather forecast. Furthermore, the forecast is becoming more accurate because the technique of hindcasting can be performed with great precision from the wealth of raw data. In hindcasting one checks the predictive information with what was observed in the subsequent period. The assumptions, theorems or algorithms used in the forecast can be checked with actual values, permitting the upgrading of the algorithms. Our farmer in the parable is now well served, and will be still better served by the Weather Service in the future.

If we now inquire into the state of the art involved in the "specie management" of the various populations of whales we find it to be poor, antiquated, and inadequate. Hindcasting and forecasting is haphazard.

In regard to the Bowhead Whale in particular, a recent

National Marine Fisheries Service report[1] had this to say, in the section on Conclusions and Recommendations (Page 22); "The question of Bowhead population abundance remains unanswered." This admission is amply substantiated by others in and outside of government.

But if one doesn't know what the population abundance is, how is it possible to "manage the living resource" rationally? The question answers itself. The only intelligent thing to do is to develop and put in place an information system, gather data for a number of years, do hindcasting, derive the needed algorithms, and only then attempt to manage the resource.

What is currently being done by government in the absence of data is not management but something else. What is clearly called for to satisfy the first requirement for rational decisionmaking is a much improved data base. It is do-able. It must be done.

2.2 CONTINUED SPECIE HEALTH

It is an interesting sidelight on the current national energy emphasis on the Arctic Coast of Alaska, that the impetus of the work by the National Marine Fisheries Service (NMFS) on the Bowhead whale cited in reference 1, is funding provided by a contract from the Bureau of Land Management (BLM) of the Department of Interior. The program under which the BLM was provided with funds in the Outer Continental Shelf oil leasing program. The purpose of a series of investigations being carried out in the Bering, Chukchi and Beaufort

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1 "Population Biology of the Bowhead and Beluga Whale in the Bering, Chukchi and Beaufort Seas." Howard W. Braham and Bruce D. Krogman, May, 1977. Work supported by the Bureau of Land Management, Department of the Interior under contract Nos. R 7120807/808, and administered by the Environmental Research Lab of NOAA.

Seas is the gathering of baseline data on the state of these Arctic Seas prior to the advent of offshore oil operations. Thus, the governmental interest in the Bowhead whale has taken on the character of an investigation of the current specie health as a baseline from which any degradation caused by future offshore oil operations can be measured. The impetus of the baseline survey is not the fact that the Inuit take the Bowhead for sustenance. The impetus is that the Bowhead and Beluga and walrus and killer whale and even the Eskimos themselves are "biological indicators" of the level of ocean pollution. This handy biological indicator function also occurs for the walrus as a benthic feeder and another mammal at the top of the biological animal chain in the Arctic. The walrus is another marine mammal which has recently been the subject of biological and specie health investigations in these same oceans.

Yet, no one will deny the importance of the continued specie health of the Bowhead whale whether jeopardized by offshore oil drilling, coastal barge traffic in the summertime, predatory whaling, natural hazards, Inuit overkills while subsistence whaling activities occur, or any other danger.

The Inuit do not want the specie to become extinct. To imply that Inuit do not care or are unaware of the implications of their own whaling practices is to say that they do not value the whale in a cultural sense, which is not the case.

The second requirement then, is to maintain continued Bowhead whale specie health. It is just as much a Federal requirement as it is a North Slope native requirement.

For a Bowhead whale specie-specific information system in the Arctic, the information gathered needs to include biological as well as population and movement data. Marine biology on this specie is therefore a key part of the project. There is much to be done to improve the sophistication of direct and indirect marine biological data gathering. The tools used to date are inadequate and are not pushing the state of the art. For example, research on animals that live in the ocean is still largely done with systems deployed on or above the ocean, not in it.

2.3 INUIT CULTURAL CONTINUITY

The third requirement to be met is the human cultural requirement. Since the U.S. cultural unit is a mere three hundred or so years old, the Inuit cultural continuity with the Bowhead whale exceeds that of the U.S. by at least a factor of 10 or more. It may be a trifle hard for the even younger Washington D.C. bureaucratic structure to understand the significance of the Bowhead to the Inuit.

A measure of the Inuit cultural commitment to the Bowhead whale is to be found in the proffered cost sharing in the proposed program. The Inuit cultural continuity is at stake. They do not want the Bowhead whale to become extinct. Controlled taking, specie population regeneration and the minimization of external threats such as marine pollution or foreign commercial taking are very much part of the overall approach to assuring the Inuit cultural continuity

with the Bowhead whale as an integral part of it.

The first requirement leads to the second and it in turn leads to the third.

3. PROPOSED INFORMATION SYSTEM

The approach that is described is the "System Approach". A problem is identified, the parts of the problem are defined or "decomposed", the system elements that can satisfy the component parts of the problem are examined and a system recomposed or synthesized which is responsive to the overall problem. Where there is a lack of appropriate information system technology, research and development needs are identified. When the technical discussion of this section is coupled with the management plan of Section 4, the outline of the proposed program becomes plain.

3.1 SYSTEM APPROACH

The Bowhead whale is a mammal. It is to be found in the Bering, Chukchi and Beaufort Seas in the spring through autumn period when the Polar ice pack recedes from the shore or where leads form in the ice pack farther from shore. The animal must breathe periodically so the ice pack provides an effective barrier in winter. The spring migration north is generally along the dividing line between the shorefast ice and the receding ice pack. Migration also occurs, or so it is believed, along leads which are further from shore and which can be thought of as terminating at that time in the spring at Banks Island in the Canadian Arctic Islands. The Bowhead whales are seen along the shores of Banks Island in the spring without any costal path between shorefast and polar pack ice having opened up. Passages along leads offshore would explain this appearance but it has not been substantiated by direct observation. Figure 1 showing

probable migratory routes is taken from the previously referenced NOAA NMFS report.

In order to count the whales involved in a migratory passage in spring and again in the autumn, it will be necessary to have appropriate sensors operating 24 hours per day, placed perpendicular to the migratory paths both near shore and well into the pack ice region. Extension of the sensor system beyond the furthest possible offshore lead and the use of more than one such sensor system along the coast will permit checking the count as well as measurement of the speed of migration.

There may also be some animals which, upon clearing the Bering Straits headed north, turn to the west past Wrangel Island on the Soviet side. A sensor system element at the Bering Straits would appear to be required too. Because of the sightings near Banks Island, there may also be some utility in considering a joint U.S./Canadian element of the information system.

To provide experimental control data on ambient noise the sensor system must be able to generate data all year round. The sensor system should be able to pinpoint the data in spatial and temporal coordinates such as distance from shore, time of day, etc. The sensor system must have the ability to gether data without becoming saturated, or distracted by non-mamalian signals such as passing ships and submarines. The system must be survivable in the rigorous weather and sea conditions and be protected from the grounding impacts of the ice on the sea floor in shallow water.

Clearly, a sensor system capable of doing these things will be useful, but it is not enough. Specie-specific sensing is required

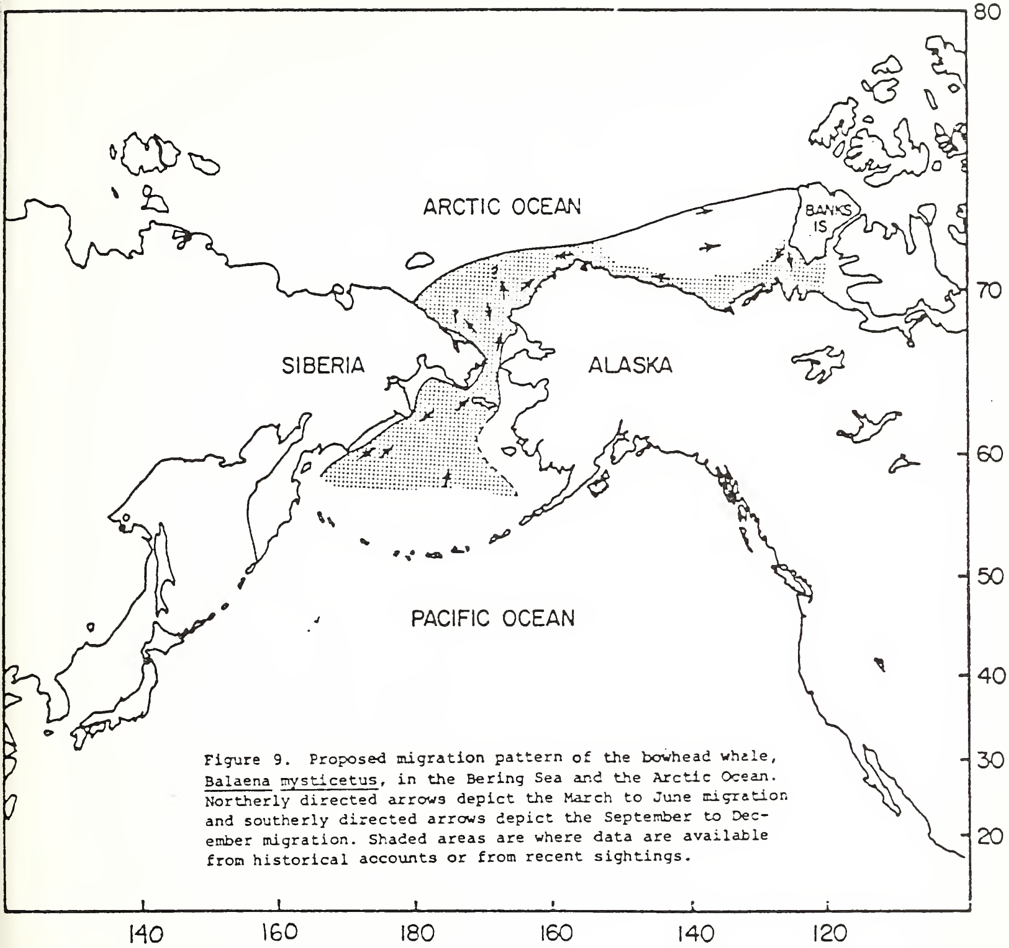

Figure 3-1 Bowhead Whale migratory routes, from ref. 1

because counting alone will not adequately differentiate one whale specie from another.

To produce specie-specific information on the Bowhead whale, and reject "noise" from other whales, the walrus, etc., requires the determination of the "signatures" of the Bowhead whales. The direct signature may be acoustic, thermal, optical, radar, or indirectly determined such as with a unique wake caused by the passing animal. Magnetic signature information would not appear to be useful, but will be reviewed.

The time, place and technique of gathering the specie-specific signatures will require another form of information system, with man in the loop a lot closer to the animal, to provide discrimination and decisionmaking in situ. This must be done to make sure the signature information is specie-specific or even individual-specific. An incorrectly identified animal signature could cause a breakdown in later pattern recognition data processing activities. Pattern determination can be in either analog form or digital form. In practice the pattern, or signature, will probably be gathered in analog form, such as a photograph, acoustic "voice print" or other, and then digitized to facilitate the automated data processing.

The advantages of digitized data and computer memory storage include the ability of the information system designer to incorporate various logical program routines in the data analysis. Thresholds of amplitude, traffic frequency, geographic location; day to day or year by year comparisons, weather, percent ice cover, water temperature, current, presence of ship traffic, etc., can all be compared by writing the appropriate instructions in computer language. In short, there is an analytic step involved in deriving the best

and most versatile on-land data processing hardware and software system to go with the sensors.

The appropriate information system will involve using other data sources too. For example, information will be provided from government and other groups such as the Marine Mammals Commission, International Whaling Commission and the National Marine Fisheries Service, as well as Inuit groups such as the Barrow Whalers Association. The last organization will be a source of first hand information from direct observation on the particular specie. The system will draw upon the Inuit's long term and subtle background in direct data gathering on the Bowhead whale during the twice yearly migrations past Point Barrow. Further down the coast to the West, the other native communities will also provide observational and background data.

The purpose of the system approach to information system design is to consider all of the factors together to derive the system capable of satisfying the original requirements consistent with the money, people, and other resources available. Placing thousands of observers at the edge of the shorefast ice may suffice for a few hours or days, but it is clearly not a year round data gathering system. A NASA satellite, an undersea active sonar system, an undersea passive acoustic array all will be investigated as system elements as well as airborne photoreconnaissance. These candidate system elements will be considered singly and in combination to satisfy the system requirements. The at-sea system elements are considered first.

3.2 AT-SEA SYSTEM ELEMENTS

Because the Bowhead whale is to be found much of the time far at sea, the information system must be capable of making the determinations at some distance from land. A detailed discussion of the capabilities of various candidate sensors and sensor systems is contained in Appendix A. The available techniques are many. Some promising new techniques are discussed and the need for sensor system development is also identified in Appendix A. For the purposes of this section, however, the at-sea system elements are discussed from the point of view of satisfying the mission requirements discussed above.

3.2.1 Existing Data Gathering Techniques

Certain kinds of data gathering at sea will occur as a part of ongoing activities without any new project-initiated effort at sea. These include.

- Direct observation by Alaska Natives from the shorefast ice.
- Airborne photography and counting during good flying weather in daylight. This is the current technique used by NOAA's NMFS and discussed in the reference 1 report.
- NASA Landsat orbiting satellites. Sensors on these satellites have already been used in the Arctic to demonstrate the difference in solar radiation reflectivity (or the albedo) of old sea ice, young sea ice and open water. Thus the existence of leads in the polar ice cap, or the rate of change of the open water conditions in the spring and autumn, will be available to the project for the asking, from existing satellite radiometric sensors.

- Navy passive acoustic arrays have been routinely used for many years to listen to undersea sounds. While the Navy emphasis is on tracking submarines, the sensors do pick up the "noise" of marine mammals. Because the data is unwanted it is filtered out. However the raw data is present from certain acoustic surveillance anti-submarine warfare (ASW) arrays.
- Periodic sightings by ships of opportunity involved in other non-related activities in the waters of the Bering, Chukchi and Beaufort Seas.
- Periodic sightings off Banks Island in the Canadian Arctic or along the Canadian coastline of the Beaufort Sea.

The above six types of at-sea data gathering system elements are part of an unstructured capability. The place of these system elements in shown on the left hand side of the diagram in figure 3-1.

In a recent article in the Arctic Bulletin, Volume 2, Number 10, published by the National Science Foundation for the Interagency Arctic Research Coordinating Committee (IARCC), the subject of "Storage, Transfer, and Usage of Alaskan Environmental Information" is discussed. As the author, Mr. David Hickok, Director of the Arctic Environmental Information and Data Center of the University of Alaska observes: "Despite the recurrent myth that knowledge is lacking, a great deal is known about Alaska; however, many sources are unpublished or obscure."

This body of existing data needs to be combined and structured for the purposes of the Bowhead whale information system use.

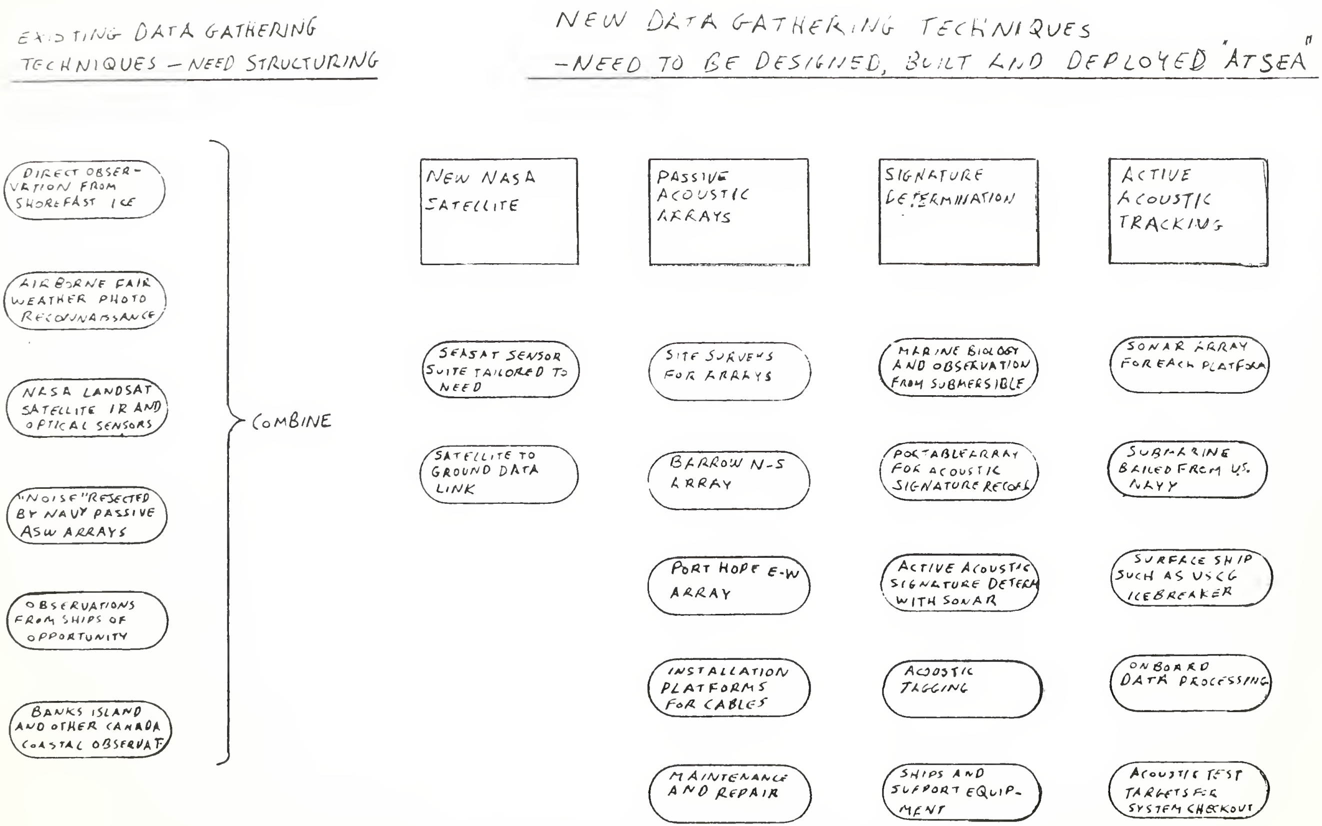

Figure 3-2 At-Sea System Elements

3.2.2 New Data Gathering Techniques

This category consists of four major activities:

- New earth orbiting satellites
- Passive acoustic arrays
- Acoustic signature determination
- Active acoustic tracking

3.2.2.1 New Earth Orbiting Satellites

The NOAA Environmental Satellite Service (ESS) is currently developing, in cooperation with NASA, an advanced earth observational satellite system similar to the LANDSAT except that it will be devoted to the observation of the 71% of the planet covered by water. It is therefore called the SEASAT. In a recent open letter to research and development organizations NOAA has solicited experiments for this satellite system. The June 23, 1977 letter describes the planned sensor suite on the satellite and asks for investigators to suggest uses of the data and/or modifications to the sensors. The first SEASAT is scheduled to be in orbit in 1978. Figure 3-3 is taken from the attachment to the SEASAT letter. It shows the regions of the world's oceans where the combination of satellite downlooking sensor and real time data link coverage will exist for the first satellite, SEASAT A. One of these regions covers the area of interest, the Alaska Arctic and Bering Seas. The satellite downlink receiver terminal ULA is in Fairbanks. A tie in would be made there.

Although the satellite will not hover over the area of interest (i.e. successive orbits process around the earth, some 18 kilometers per orbit at the equator, and the useful downlooking angle is small during the orbital period), the periodic data at orbital intervals

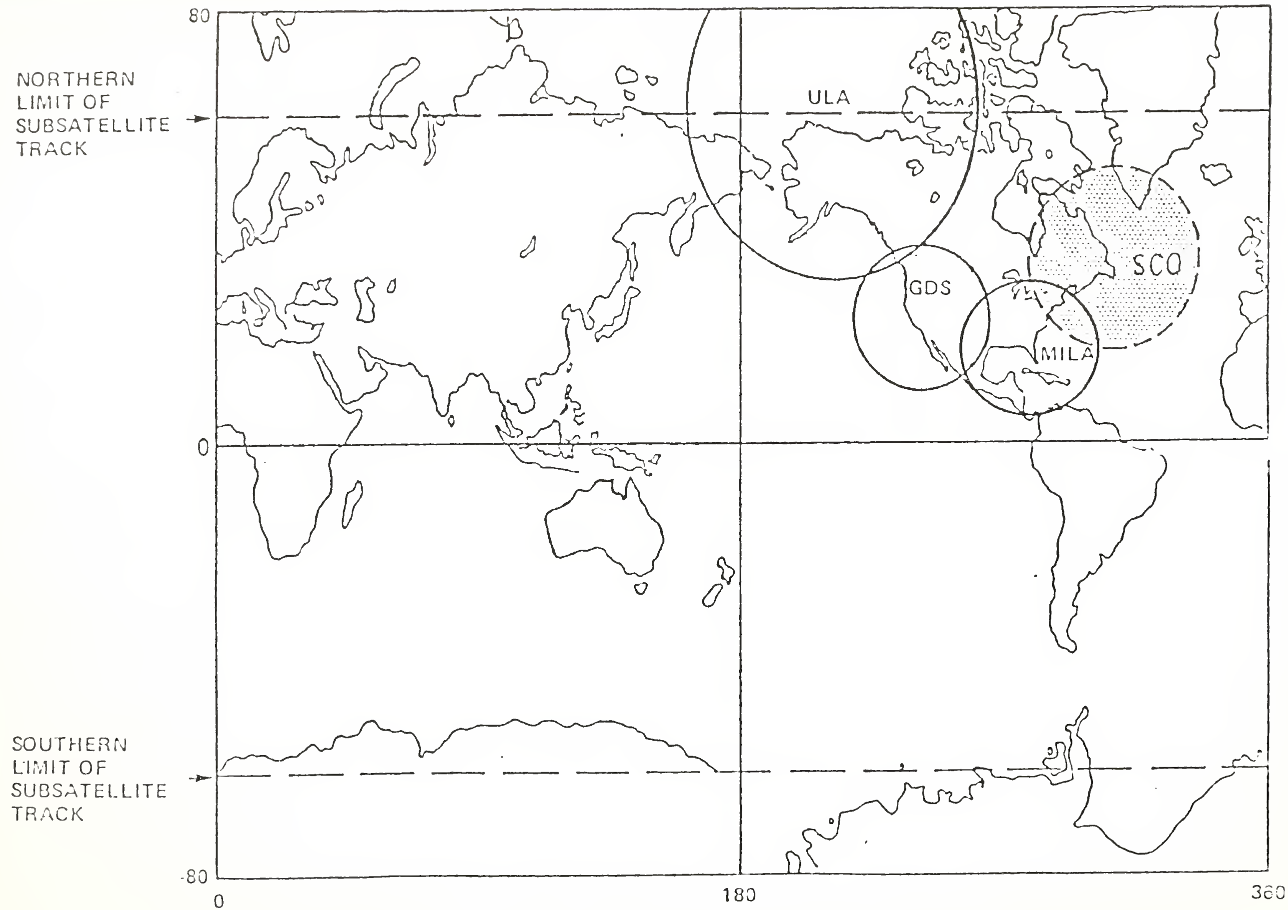

Figure 3-3 Ground Stations Coverages for SEASAT A Satellite

will be very useful.

The subject information system will contain at least one set of experimental procedures and hardware for the SEASAT and will require the use of a portion of the downlink to Fairbanks. The optical, infrared, radiometric and even the radar altimeter will be useful to the Bowhead whale information system. The LANDSAT has already shown that it can see oil slicks at sea through the use of special data processing on the raw optical sensor data. This has been reported by Morris Deutsch of the U.S. Geological Survey at Reston, Virginia. There is every reason to believe that under favorable conditions the SEASAT will be able to discern the movement of whales in migration. The data are there, the difficulty will be in eliminating noise, in having adequate angular and range resolution for the satellite sensors, plus favorable timing. While much of the subject information system effort related to the SEASAT will be on-land data processing, some of the effort involves the design of the "at sea" downward facing satellite sensory experiments, for the case of the Bowhead whale dat

3.2.2.2 Passive Acoustic Arrays

The principal new system element of the proposed information is the passive acoustic array. Section 4 discusses issues dealing with its design, deployment and cost. The technical discussion herein deals with it as a given. It is the key system element at sea. The discussion assumes that a passively determined acoustic signature of the Bowhead whale has been separately determined. The gathering of the signature information is covered in section 3.2.2.3, below.

The principal difficulty in laying in a pair of orthogonal arrays offshore in this region is the ice. A second difficulty is posed by the presence of undersea permafrost, although once the array is installed this acoustically reflective surface may prove very useful to the array. This aspect is discussed in the Appendix A.

The offshore arrays are placed nominally as follows:

I. North-South array located due north of Point Barrow.

II. East-West array located, nominally, due west of Point Hope.

By the use of two such arrays, both on the order of 50 miles in length, the Bowhead whale can be tracked along the migration path as well as farther at sea when leads open up in the pack ice. The precise design of the arrays will depend on the results of site surveys during which current structure, depth contours, soil samples and extent of the offshore permafrost will be determined. The site surveys can be conducted during the summer by ship off Point Hope. With a favorable stand off distance for the pack ice for about 6 weeks, the site survey might be possible in a single summer season off Point Barrow.

There is another way that both site surveys could be done for the water depths in excess of 150 feet. The method would utilize the services of a U.S. Navy early vintage nuclear submarine as a sensor platform. In 1976 a Navy nuclear submarine participated in an under-ice data gathering activity under the AIDJEX (Arctic Ice Dynamics Joint Experiment) program coordinated by the IARCC. The experiment was performed in "the AIDJEX Ocean" some 300 miles North of Barrow, sponsored by the Polar Programs Office of the National Science Foundation. The task was performed on the

submarine SSN [redacted] as part of a study of the keel (underside) ice pressure ridges. This was a "survey" mission directly analogous to the mission that the Bowhead passive acoustic array system requires.

Once the precise nature of the ocean bottom over the array route is known the array can be built. The array cable is prepared for deployment from a cable laying ship. Again, the potentially available Navy cable laying ship type would be used for the deeper water out to the edge of the icepack. In the shallow water, in the depths where ice pressure ridge keels will ground on the ocean bottom, it is necessary to trench and/or drill into the bottom to get below the ice scour depth. Part of the route from shore above the high water mark can be handled with a horizontally deviated oil well drilling technique. This technique has been successfully used in installations of some of the Navy arrays elsewhere. It is known to work. Drilling through unconsolidated silt, while faster than drilling through the permafrost layer under the ocean, will require setting in a conductor pipe. The array is fed into the drilled hole from shore using a messenger line for the cable pull. This has been done also. Below the water depth where ice can scour, the cable is permitted to lie along the ocean floor. The water depth drops off fairly rapidly close to shore North of Barrow because of the presence of the offshore Barrow Canyon. The same fairly rapid falloff is true off Point Hope in a westerly direction.

There is also the technique for the deeper water, of performing some of the array installation by pulling through a hole cut in the ice pack. This should work off Point Hope, however, the icepack moves unpredictably off Barrow. Finally, it would also be

possible to reconfigure a bailed Navy submarine to perform the cable installation in sections under the ice, on a fully weather independent basis. The rapidity with which the installation can be accomplished is directly related to the sophistication of the support system used.

The arrays and the support systems at sea must be configured for ease of maintenance and repair. The system design will bear all of these factors in mind to assure that the non-operational, "down" time of the passive acoustic array is small and infrequent.

3.2.2.3 Signature Determination

While the array installation and operation will have a strong civil engineering emphasis, and will be designed to track the Bowhead whale at long distances, the signature determination function involves close human observer activity, under the sea.

The offshore area from Point Barrow East past Smith Bay to Cape Halkett is thought to be a region where the Bowhead whale congregate prior to the fall migration to the west past Barrow. This is the region where the whale will be observed, recorded and possibly tagged. The difficulty with tagging comes down to four largely mutually exclusive requirements.

I. How to get close enough to individual animals to attach a distinguishing tag.

II. How to choose a tag which will not itself alter the animal's behavior. For example, a strong acoustic transmitter might cause disorientation of the whale's acoustic sensing capability.

III. How to attach a tag which will not cause physical

wound or injury or change the animal's hydrodynamic qualities.

IV. How to perform the tagging function on a specie which is supposed to be "untouched". A tagged Bowhead is not a natural Bowhead, it has a "parasite" attached.

Without, at this time, recommending that attempts be made to tag individual animals with acoustic beacons, it can be observed that passive acoustic tracking would be greatly facilitated by the use of a beacon on each moving target being tracked. Acoustic tagging of walruses has been attempted with mixed success in the Bering Sea.

The preferred method of tracking the animal in its most natural condition is to obtain its "voiceprint" as a signature as well as to measure and record unique or specie-specific hydrodynamic shape and motional acoustic energy spectra, tail flipper rate and so on. This is far from a fully developed art but appears to have promise.

To gather these data, the operation will involve teams of marine biologists and acoustic signature gathering technicians working with small manned submersibles and portable acoustic arrays underwater in the close vicinity of the Bowhead whales. This will be challenging work, but it will lead to measurably improved data on, and understanding of, the Bowhead whale in its natural environment. The small manned submersibles will require discrete and quiet support close, but not too close, to the whales.

A final signature gathering technique will be considered after the generally passive data and observations have been completed. This type of signature is that which involves a modulation of the

doppler shift of an active sonar beam caused by, for example, the tail flipper rate of oscillation as the animal moves away or approaches at a certain speed through the water. This type of active sensing has been demonstrated to yield some specie-specific signature information when applied to fish types in the ocean. It offers some limited use promise in the Bowhead whale case if some unique "doppler modulation signatures" for the Bowhead whales can be found.

3.2.2.4 Active Acoustic Tracking

Although the primary thrust of the Bowhead whale information system is to passively track these marine mammals, there exists a need for some active sonar capability on moving ship platforms. The ideal platform would be a small, maneuverable and quiet submarine with endurance and speed. Unfortunately such a craft does not exist. However, an early vintage Navy nuclear submarine, specifically the quiet electric drive SSN 597 TULLIBEE, would be very close to the needed configuration. The North Slope natives will, with the cooperation of NOAA and the Department of Interior, make a representation to the Navy to gain access to this particular submarine. The whale tracking mission will continue for two seasons.

The submarine will be outfitted with a suitable active and passive sonar array and used under the Arctic ice and under water in the vicinity of the Bowhead whales. Because the submarine has the endurance to keep up with the migrating whales, the submarine will acquire large volumes of data. Onboard data processing will facilitate the later evaluation of the data. Time and navigation coordinates are already recorded and can be integrated into the whale data.

In addition to the submarine, less optimum sensor platforms are the surface ships such as Coast Guard icebreaker ships. An icebreaker ship could not, however, follow the Bowhead whale migration path through leads in the icepack to the Banks Island areas, whereas the submarine can.

In addition to the submarine, ships and their sensors, it is important to have a few test targets to acoustically mimic the Bowhead whale for equipment shakedown cruises outside of the area where the Bowhead is found.

The above discussion has addressed various aspects of the at-sea system elements. The next section deals with the on-land system elements.

3.2.3 On Land Data Analysis

The purpose of the on-land data analysis part of the information system is to make sense out of the various inputs from the at-sea sensors based on the logic and policy of the investigation. Data will be collected in real time in some cases, but more likely most of the data will come in at convenient times or in some cases in hand carried form such as photographs and magnetic tapes. The magnetic tapes may contain either raw analog recordings of data, processed analog data or digitized recorded data. The various elements of the on-land data analysis function are shown in the block diagram in Figure 3-3.

3.2.3.1 Analog Data Inputs

The left hand side of the block diagram in Figure 3-3 show 6 different analog inputs. These data include:

- Photographs, infrared (IR) images, radar display data and

verbal notes recorded on magnetic tape or paper from overflights of the migrating whales by reconnaissance aircraft. The data will be required to be precisely addressed and cataloged as to time, navigation coordinates, ambient conditions such as weather, percent of ice cover, etc., As a body of data such as photographs of individual whales is collected, a certain amount of optical or IR pattern recognition may be possible before the data is stored or transmitted back to the on-land data processing facility, nominally located in Fairbanks near the satellite communications terminal.

- Magnetic tapes containing analog recordings of the SEASAT A sensor channel inputs. These data will be received periodically from the satellite's downlink communications channels and will be available at the satellite ground terminal in Fairbanks. Data will include optical, IR and an altitude measuring narrow beam radar. Considerable analog signal processing and enhancement will be performed on these data, before being transmitted over land lines to the subject program's data analysis facility, for analog storage. The satellite data will be accurately addressed and time coded.
- The passive arrays will produce large volumes of continuous data although the analog signal bandwidth is not large. The data will be from multi channels of the array. Some analog signal processing can be done on shore prior to transmittal of the data back to Fairbanks by either land lines or communications satellite links. Because more than one array is involved, the multichannel information will be transmitted

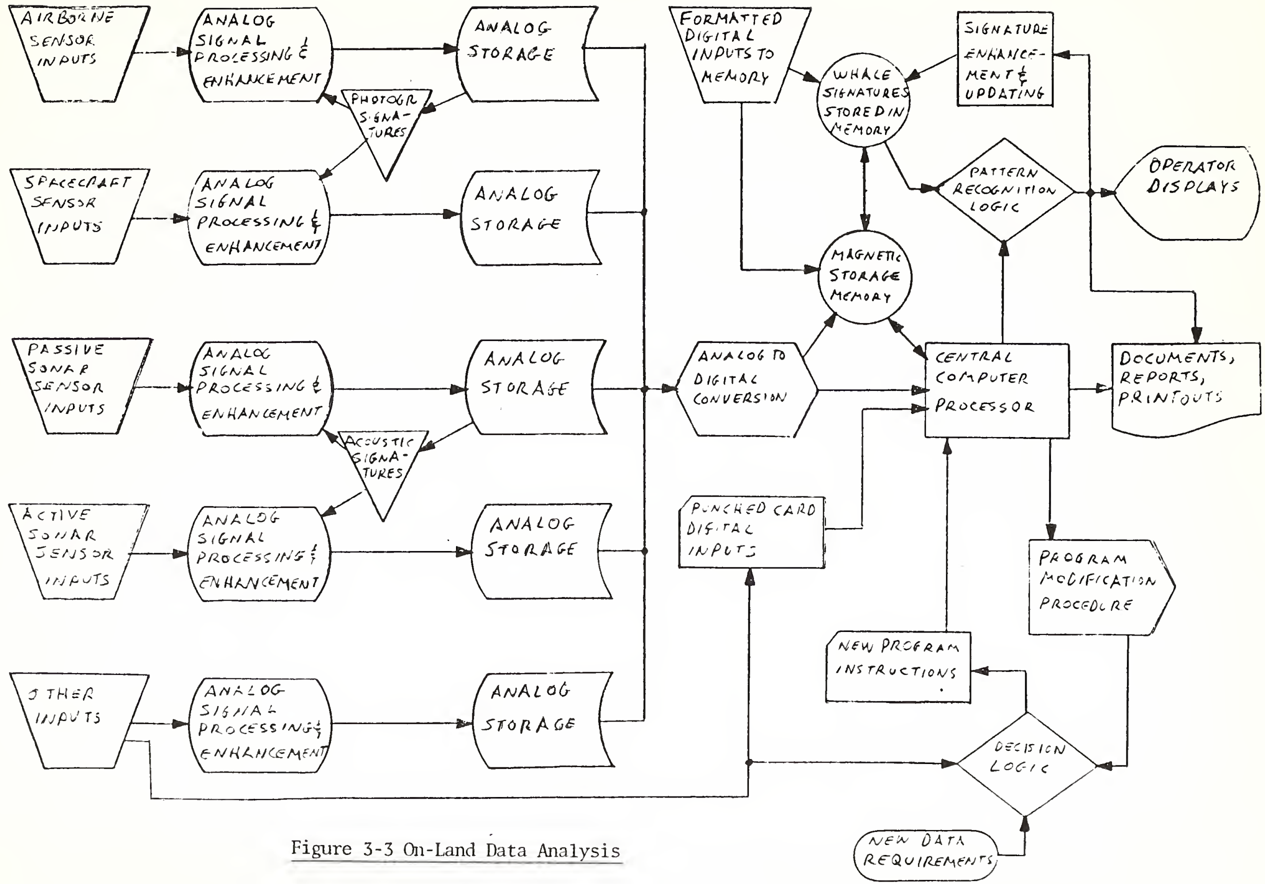

Figure 3-3 On-Land Data Analysis

direct and followed up by hard copies, hand carried at a later time. The important comparisons that can be conducted at each array on the passive acoustic data are: analog phase, amplitude, delay, population count, and speed of advance past a single hydrophone or perpendicular to the line of hydrophones. In addition to these analog processes the data from the two arrays can be compared at the data analysis facility to produce much additional information. Once these analog comparisons are performed, the data is put into analog storage.

- The active sonar sensors on the various platforms previously discussed will produce much data which will be processed and formatted onboard prior to transmittal to the data analysis facility. The onboard data processing is done partly to benefit the onboard investigators so that the tracking technique can be improved and the data improved by virtue of the real time feedback. Once the data has been transmitted to the data analysis center, this analog feedback is no longer possible. Unlike the passive fixed array data, the data taken from a movable submarine or surface ship can be improved as one learns tracking technique. Because the platforms move it is particularly important to have a continuous navigation position determination to address the data.

- The last category of inputs is data from a variety of other sources including the cetacean noises recorded by the Navy in their arrays. These data normally disposed of or filtered out could be very useful if one can learn the discrete acoustic signatures of the Bowhead whale specie.

Sightings of the Bowhead off Banks Island by Canadian observers is another unstructured and unformatted raw data source in the analog form. Data on associated phenomena such as weather, percent of ice cover, presence of surface ships or barges in the areas of interest all represent various categories of related data which will be used in the data analysis function. These data are both signal processed and recorded in analog form or, as appropriate, are punched into cards as inputs and instructions to the computer logic sequences.

- A provision has also been made in the system for direct digital inputs to the computer memory. While digitally formatted whale signatures are expected to be a derivative of the central data processing system, there is a provision for inputs to the digitized memory directly, if the data meet certain formatting criteria such as least significant bit size, time base interval choice, etc.

3.23.2 Computer Processing

The various analog inputs are combined in an analog to digital coverter where the various data sources are put into a standard digital format. The computer than performs various functional comparisons on data based on instructions punched in. There is a provision to change the computer programs and alter the instructions. The outputs of the process are displayed, on command, for the operators and scientists, and data is then printed out as appropriate. The displays can provide either analog or digital information.

Consider, for example, the process by which the whale data, derived by the acoustic array, is compared with the acoustic signature

of the whale contained in the computer memory bank. The signature may have been digitized to the closest 0.2 cycles of frequency in the range, say, of 1 cycles to 10 cycles per second (Hertz) (Hz). The discrete whale signature may contain a very high amplitude at 5.5 Hz, where amplitude may have been digitized to the nearest Decibel (db) with reference to a standard reference acoustic signal strength. In the example, the digitized element of the signature is: "At 5.5 Hz ± 0.1 Hz the amplitude is + 35 db." A new recording of data is received from the acoustic array and its digitized signature reveals upon analysis to be only + 10 db at 5.5 Hz. Either the animal is not the same one, or the specie identification was wrong, or the right animal is now putting out different acoustic signal levels over the frequency spectrum of interest. The pattern recognition logic in the computer is one of the most powerful of the potential data processing tools that will be made available to the investigators. The effectiveness of the pattern recognition is, however, still very much governed by the quality and lack of ambiquity inherent in the originally observed and recorded data at sea. Thus the data analysis function is part of a team effort towards the project objective.

Inherent in any sophisticated information system are the feedback paths that permit the learning process to occur so that better and better understanding results as the experimental technique improves. There appears to be no limit other than dollars and time to deriving a full understanding of the specie, its migratory habits, population count, reproductive/replacement rate, predatory population shrinkage, etc. The level of understanding of the specie is going to greatly expand in a few years time through the use of the information system.

3.4 WHALING SHIP MONITORING

There exists a small but finite possibility that some unauthorized taking of the Bowhead Whale is still going on in the Bering Sea area by commercial whalers. The efficiency of commercial whaling techniques, the rapidity with which the taken whale can be brought aboard and processed into non recognizable form, and the quality of the Bowhead meat suggests that an incentive still exists for some pirate whaling ship activity.

The current dialog between the tuna fishermen and the NOAA NMFS in regard to the inadvertent killing of porpoises along with the tuna in the tuna nets serves as an indicator of the possibility of some unauthorized whaling. It is understood that "controlled experiment" was recently run between two U.S. tuna fishing fleets.

In the first, NMFS observers were put on each fishing boat, and a visual count was made of the number of porpoises killed per day in the course of tuna netting. This count was compared with the log of the ship captain on the number of porpoises netted and there was close agreement between the two figures. The ship captains' logs on the porpoise netting were entered into the official NMFS records upon return to port. A porpoise-to-tuna statistic was thereby established.

In the second case, no observers were sent out on the tuna boats. Upon return to port, the data from the ship captains' logs on porpoise kills showed a kill rate only one sixth as large as on the ships with

official monitors on board. The accuracy of the ships' logs in the second case is questionable.

In the case of the possible pirate taking of the Bowhead whale by commercial whalers, the problem is one of monitoring. Monitoring can be accomplished by observers on board each ship which would be difficult by definition. Alternatively improved monitoring by Coast Guard aircraft and ships could be used but there is a lot of ocean to cover. The use of satellite borne sensors to identify and keep track of each ship in a given ocean area is possible but not being done at present for the whaling ship type. All in all, advanced techniques for gathering better information on what is happening to the Bowhead Whale, as a result of unauthorized taking by commercial whaling ships, is far from being fully implemented. Even if some unauthorized taking is shown to have occurred, there remains the extent to which international policing of the activity will be carried out. The recent implementation of the 200 mile economic zone for protecting the U.S. fisheries resources is a step in the right direction if the law is followed up by concrete actions, including the occasional prosecution of the offender.

APPENDIX H

This appendix contains letters sent by NMFS to several Eskimos regarding the possibility of sending an Eskimo representative to the 29th Annual Meeting of the IWC.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
P. O. Box 1668, Juneau, Alaska 99802

LAW ENFORCEMENT BRANCH

April 29, 1977

NATIONAL MARINE FISHERIES SERVICE
RECEIVED
MAY 5 1977
Marine Mammal and Endangered Species Division

Mr. Arnold Brower, Sr.
Barrow, Alaska 99723

Dear Mr. Brower:

This is an overdue note to thank you, and all whaling captains and Whaling Association members, for the discussion and meeting in Barrow on March 2, 1977.

I appreciate the community interest in preserving your whaling culture and hope we can maintain useful contact on the subject in the future.

Would the Whaling Association be interested in sending a representative to a work session or meeting of the International Whaling Commission? Meetings of the IWC are attended mainly by commercial whaling people and scientists from various countries, and also by people seeking to stop all whaling. Much public opinion focuses on commercial, and/or wasteful, killing in excess of peoples real need. Since Eskimos are the only subsistence users of bowhead whales, it would be informative to all interested parties if the Eskimo viewpoint could be represented.

Probably the most effective person would be someone who can speak for past ways of living in the Eskimo culture, and also about the importance of bowhead hunting in the present day. A whaling leader of long experience, recognized in your area and as far as Point Hope, would be most helpful on the whaling subject.

If your Association does select a leader, as spokesman for whalers, he should attend an IWC working group meeting scheduled in Washington, D.C. during the first week of June. It may be possible for my agency to provide some travel funds. Please write or phone me (586-7225) if your people are interested, and I will try to answer any questions you may have.

Did the Whalers Association reach agreement on controlling the level of bowhead harvest in the Barrow area this year? As we discussed at our meeting, our agency is concerned with the trend of increasing bowhead kills by Eskimos. Mr. Ed Wightman, our Enforcement Agent that attended the meeting with me, will be in the Barrow area occasionally during springtime and probably will visit with you.

As you know, there is a lot of public concern over any whale killing, and people are asking our agency if Eskimos are reducing their harvest this year. I am enclosing a February 3, 1977 letter to the Secretary of Commerce from MONITOR, INC., a group interested in sea mammals. I would be interested in your comments on the views presented in their letter.

Sincerely,

Mil Zahn

Mil Zahn
Assistant Special Agent in Charge

Enclosure

cc:
Amos Lane, Point Hope
Ed Wightman, Anchorage

LAW ENFORCEMENT BRANCH

April 29, 1977

Mr. Amos Lane
Point Hope, Alaska 99766

Dear Mr. Lane:

Enclosed is a copy of the bowhead whale research report that I promised to send, and a marine mammal chart that might be useful in the local school.

Also, I am attaching a copy of a letter to Arnold Brower, Sr. regarding the possibility of sending an Eskimo representative to a meeting of the International Whaling Commission. I wrote to the Barrow people on the subject because their Whaling Association, as a group, can reach a number of whalers for comment and decision.

Also, with the letter to Mr. Brower, is a letter from MONITOR, INC., (a group interested in sea mammal protection) to the U.S. Secretary of Commerce. As you can see from this material, there is a lot of public interest in reducing the overall bowhead kill by Eskimos.

I appreciate you and the other Point Hope whalers meeting with me last winter and hope we can stay in touch on the subject of whaling harvest trends.

Sincerely,

Mil Zahn
Assistant Special Agent in Charge

Attachment

MCZahn/sra

bc Wightman

LAW ENFORCEMENT BRANCH -

May 3, 1977

Mr. Dale B. Stotts
Subsistence Affairs
North Slope Borough
P. O. Box 69
Barrow, Alaska 99723

Dear Dale:

Attached is a copy of my April 29, 1977 letter to Arnold Brower, Sr., asking if the Whaling Association is interested in sending a representative to a meeting of the International Whaling Commission.

Did you ever complete a copy of our meeting transcript? Give me a call when in Juneau and maybe we can meet for lunch.

Sincerely,

Nil Zahn
Assistant Special Agent in Charge

Attachment

NCZahn/sra
Wightman

To: F33 Tom Andrews 634-7461 pg 1 of 7

LAW ENFORCEMENT BRANCH

May 3, 1977

Mr. Rex Tuzroyluk .
Point Hope, Alaska 99766

Dear Rex:

Enclosed are copies of the bowhead whale research reports that I promised to send, and a marine mammal chart that might be useful for display in an office or store.

Also, I am attaching a copy of a letter to Arnold Brower, Sr. regarding the possibility of sending an Eskimo representative to a meeting of the International Whaling Commission. I wrote to the Barrow people on the subject because their Whaling Association, as a group, can reach a number of whalers for comment and decision.

Also, with the letter to Mr. Brower, is a letter from MONITOR, INC., (a group interested in sea mammal protection) to the U.S. Secretary of Commerce. As you can see from this material, there is a lot of public interest in reducing the overall bowhead kill by Eskimos.

I appreciate you and the other Point Hope whalers meeting with me last winter and hope we can stay in touch on the subject of whaling harvest trends.

Sincerely,

Nil Zahn
Assistant Special Agent in Charge

Attachments

bc Wightman

HCZahn/sra

LAW ENFORCEMENT BRANCH

May 27, 1977

Mr. Arnold Brower, Sr.
Barrow, Alaska 99723

Dear Mr. Brower:

I am pleased to learn that you are planning to represent the Barrow Whaling Captains Association at the meeting on bowhead whaling, to be held June 8, 1977 in Washington, D.C.

The constructive efforts by you and Dale Stotts, and the support of the Whaling Captains, are absolutely essential to establish a working communication between subsistence whalers and other people with an interest in whales. As you know, the Eskimo whaler is facing criticism by many segments of the public, and the high bowhead kill this spring raises the possibility of regulatory proposals. Your testimony on June 8 will be very helpful in representing the Eskimo interest and in correcting any wrong impressions that people may have.

Enclosed is a copy of the notice of the June 8 meeting on bowhead harvest by Alaska Natives. I plan to attend the meeting also, and look forward to seeing you there.

Sincerely,

Mil Zahn
Assistant Special Agent in Charge

Enclosure

cc:
F33, ~~[illegible]~~ Jensen
Dr. Aron

MCZahn/sra

NATIONAL MARINE FISHERIES SERVICE
RECEIVED
JUN 1 1977
Marine Mammal and Endangered Species Division

June 21, 1977

To Hil Zahn
Assistant Special Agent in Charge (Mammals)

Edward W. Wightman

From Edward W. Wightman
Senior Resident Agent

Subject Barrow Trip Report

Synopsis

The Spring 1977 Bowhead whale harvest by Alaskan native subsistence hunters has been closely monitored by research biologists and law enforcement personnel.

During May, Eskimo whaling camps located near offshore leads on the sea ice adjacent to Barrow were visited and information gathered.

Whaling activities were observed for compliance with both the Endangered Species Act of 1973 and Marine Mammal Act of 1972.

Patrol Activities and Observations

During the period May 7 to May 13, 1977, I traveled to Barrow for the purpose of observing the bowhead whaling activity occurring near Barrow.

Barrow Interviews

On Thursday, May 12, 1977, ASIC Hil Zahn requested I contact Arnold Brower, Sr., concerning the Barrow Whalers Association sending a representative to the International Whaling Commission's work session to be held in Washington D.C., in late May. It was further decided that the North Star Borough Mayor's office should be included in determining who the representative should be as it also affected other whaling villages in the Borough.

On Friday, May 13, 1977, I met with North Star Borough Mayor Eben Hopson and Arnold Brower, Sr. Upon requesting they select a representative, Mayor Hopsen immedately became abusive stating, "The Whaling Commission has no business here". "No, we will not send anyone", and that he thought sending someone to the meeting was a "whole bunch of malarky", indicating "as far as the Eskimo is concerned, we have no problem" with the whales. He then demanded to know how many bowheads other nations had taken. Mr. Brower was very quiet and did not participate in the harangue. After the meeting, Mr. Brower indicated that he thought it was very important that a representative of the Whalers attend the I.W.C. working session. He indicated he would contact the Association members and a representative would be selected.

POPULATION BIOLOGY OF THE BOWHEAD (*Balaena mysticetus*) AND BELUGA (*Delphinapterus leucas*) WHALE IN THE BERING, CHUKCHI AND BEAUFORT SEAS

by

Howard W. Braham *

and

Bruce D. Krogman *

* Marine Mammal Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way, N. E., Seattle, WA 98115

Northwest and Alaska Fisheries Center Processed Report, May 1977.

Abstract

Bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whale distribution and abundance are summarized using data collected in 1976 and from the literature. Aerial and ice camp surveys were simultaneously conducted in an effort to delineate migratory patterns in the spring.

Spring 1976 census counts of whales near Barrow, Alaska, indicate that significantly fewer belugas than bowheads were seen using the ice camp counting method. Preliminary results reveal that aerial survey methods are better for delineating distribution, whereas ice camp counting methods will provide more reliable indices of population abundance.

An hypothesis is proposed delineating the spring migration of the bowhead whale in the Chukchi and Beaufort Seas: in the spring an unknown segment of the population migrates in off-shore leads north past Point Barrow, Alaska, to Banks Island, Canada, before entering the southeast Beaufort Sea in the summer. This modifies the existing hypothesis that the migration occurs near-shore along the north coast of Alaska.

Copulatory behavior and a young of the year bowhead calf were observed in early May 1976 near Point Barrow, Alaska, providing evidence that reproduction of the species occurs during the northward migration.

Fall concentrations of bowhead whales were observed in near-shore waters of the western Beaufort Sea. Reasons for this behavior are not yet clear. The coastal area from Smith Bay to Pt. Barrow should be closely studied prior to any oil or gas exploration.

Table of Contents

Introduction

This report is the culmination of the first year of research on the distribution and abundance of bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whales in the Bering, Chukchi and Beaufort Seas, as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP).

The purpose of the report is to provide a summary of the current knowledge on bowhead and beluga whale distribution by integrating published and unpublished accounts with sighting data collected during 1976. Our intent is to provide a document which can be immediately transmitted to other scientists, managers and administrators who are in decision or policy-making positions.

Research on the bowhead whale at the Marine Mammal Division was initiated by Dale Rice in 1961-62, and was resumed in 1973 under contract with Floyd Durham (1975). The collection of biological data from animals harvested by Eskimos is an ongoing program at the Division (Fiscus and Marquette, 1975). Although Foote (in Mansfield, 1971) counted bowheads as they passed Pt. Hope during the early 1960's, to date there has been no systematic study of the numbers of bowhead and beluga whales which migrate within leads (cracks of open water in the ice) from the Bering Sea into the Chukchi and Beaufort Seas. It was principally because of this data gap that our research under the OCSEAP program was initiated.

Bowhead and beluga whales may be particularly vulnerable to the activities of oil and gas development because they migrate through the Chukchi and Beaufort Seas in near-shore leads along the coast of Alaska. Because both species are seasonally harvested, and because their population sizes are unknown, it is essential that they be intensively studied in order to determine their current status. With the exception of the Eskimo take, bowhead and beluga whales are protected under the Marine Mammal Protection Act of 1972 (MMPA). The bowhead is further protected under the Endangered Species Act of 1973. As such, private and public energy development groups are obligated to determine which, if any, energy-related activities might be detrimental to the species. To this end, we expect over the next several years to further delineate local movements, migration patterns, and abundance.

Our experimental plan for delineating distribution and abundance is to combine data collected by a counting team stationed on shore-fast ice near Eskimo hunters with data collected from aerial surveys. Sighting data from each survey method will then be compared to establish overlap, variability, and reliability.

This report is divided into six sections: Introduction, Current State of Knowledge, Study Area, Methods and Materials, Results and Discussion, and Conclusions and Recommendations. The Current State of Knowledge section provides a brief historical account of the available information on distribution and abundance from published and unpublished literature. The

Results and Discussion section provides more recent information on distribution, and estimates of how many bowhead and beluga whales passed near Barrow in 1976. This section also includes heretofore unsummarized data collected on bowhead whales by other scientists during 1974-1976.

Current State of Knowledge

Bowhead whale

From March through June bowhead whales migrate from the Bering Sea into the Chukchi and Beaufort Seas. They generally begin passing through the Bering Strait in late March and early April, as evidenced by our 1976 sightings and harvest records at Wales (Bailey and Hendee, 1926) and Point Hope (Johnson et al., 1966). At Barrow, Alaska, the arrival of animals can vary by two weeks in late April to early May (Maher and Wilimovsky, 1963; Foote, 1964; Fiscus and Marquette, 1975), depending upon ice conditions. Migration in the southeastern Chukchi Sea has been described as occurring in "waves". The first and second waves are believed to be sub-adults; the third wave is comprised of adults (Maher and Wilimovsky, 1966; Durham, 1975). This assumption is primarily based upon Eskimo whaling statistics (Marquette, 1976). The end of the migration period past the northwest coast of Alaska (Pt. Hope and Barrow) is unknown, as ice conditions prevent observers from staying on the ice past early June. By mid-May bowheads begin arriving in the Canadian Arctic, first near Banks Island, and later near the Mackenzie River delta, where they remain through the summer (Sergeant and Hoek, 1974; Fraker, 1977).

Spatial distribution of whales from early June through August in the western Beaufort Sea is poorly documented. Fiscus and Marquette (1975) recorded that the first catch of the fall Eskimo whaling season is in September. Hence, bowheads may be absent from the western Beaufort Sea during the summer. Early commercial whaling records indicate that July through September was the favored time to hunt bowheads in the northern Bering-southern Chukchi Seas and eastern Beaufort Sea (see Cook, 1926; Bodfish, 1936; Starbuck, 1964; Bockstoce, 1977; Fraker, 1977). Mansfield (1971) briefly summarized the distribution of bowheads in the western Canadian Arctic, near Banks Island, using recent sighting records.

The spring migration route east of Barrow is poorly defined. Also, it is unclear what percentage of the total population moves past Barrow. Perhaps some animals remain in the northeastern Chukchi Sea throughout the summer.

The size of the bowhead whale population in the Bering Sea and Arctic Ocean prior to commercial exploitation is open to conjecture. Townsend (1935), Hegarty (1959) and Starbuck (1964) list information concerning commercial whaling prior to 1920, including names of vessels and dates of departure and return, number of whales taken per ship, and the waters where each vessel whaled. Comparing harvest records from Townsend (1935) and Starbuck (1964), the bowheads taken prior to 1850 were undoubtedly from the Atlantic Ocean populations, and those taken after 1850 were predominantly from the Bering Sea population. Scammon (1874) indicates that whalers first searched for bowheads in the Bering and Chukchi Seas in 1847-48.

Using Townsend's (1935) data as a sample of the total bowhead catch from the Bering Sea and Arctic Ocean, an assessment of the relative size of the early population can be made. Figure 1 is a histogram of Townsend's records. It depicts the trend in the number of bowheads taken by commercial whalers (histogram), and includes an overlay graph of the whaling effort. In just 25 years (1850-1875), the number of bowheads harvested per five year interval declined 82%, whereas the whaling effort declined 33% (Figure 1). Such a rapid decrease in the number of whales taken suggests that the size of the pre-exploited population was not large. This is also suggested by the fact that the annual harvest from 1875 to 1919 remained almost constant while the effort fluctuated (Figure 1). The dramatic increase in catch per unit effort from 1890-1904 was a result of more efficient whaling with the introduction of the steam ship whaler (Bockstoce, 1977).

Assuming a stable population, Rice (1974) estimated the western Arctic Ocean and Bering Sea bowhead population to be 4,000-6,000 animals between 1868 and 1884. It appears now that this was not a likely assumption (Figure 1). Since early whaling records have not been systematically investigated, no reliable estimate can be made of the pre-exploited population level of bowheads in the Bering Sea and western Arctic Ocean using Townsend (1935).

Current stock assessments have been made by Sergeant and Hoek (1974), who estimate the number of bowheads in the Beaufort Sea to be "in the low hundreds". In August and September of 1976, Fraker (1977) sighted about 80 animals (probably includes duplicates) north and east of the Mackenzie delta area in the eastern Beaufort Sea.

Bowhead whales are believed to feed on copepods, amphipods and euphausiids. Species identified in whale stomachs from these groups include: _Calanus hyperboreus_, _Parathemisto libellula_, _Thyanoessa inermis_ and _T. rauschi_.

Beluga whale

The beluga whale (also known as the belukha and white whale) is usually found in shallow bays or estuaries north of 40° N. Latitude. In Alaskan waters there are at least two resident populations: one in Cook Inlet consisting of perhaps 300-400 animals, and the other in eastern Bristol Bay numbering 1,000 to 1,500 individuals (Klinkhart, 1966). The population size north of Bristol Bay may reach 8,000 individuals (DEIS, 1976). Belugas begin their northward migration to arctic waters in March and April, travelling in groups as large as 100-600 (Bailey and Hendee, 1926; Kleinenberg et al., 1964; Johnson et al., 1966). Locations in the Bering Sea from which belugas migrate are not clear. In the western Canadian Arctic the summer-fall population reaches 4,000-6,000 animals (Sergeant and Hoek, 1974; Fraker, 1977).

Belugas follow leads in the pack ice which extend into the Bering Sea and Arctic Ocean. Once through the Bering Strait, some animals are reported to move along the Siberian coast (Kleinenberg et al., 1964), while others follow the Alaskan coast (Sergeant and Hoek, 1974; Sergeant and Brodie, 1975). We do not know what percentage of the population moves into the western Chukchi or the Beaufort Seas.

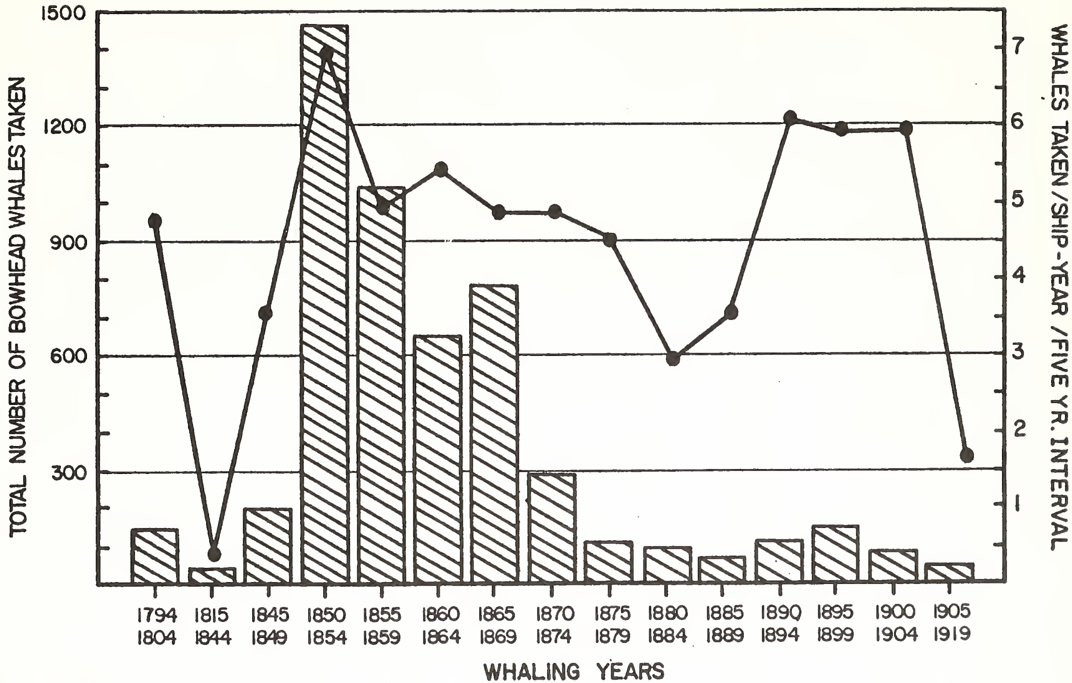

Figure 1. Chronological account (histogram) of the bowhead whales taken by commercial whalers, 1794-1919. Records prior to 1850 are considered Atlantic Ocean data; after 1850 they are considered Bering Sea-Arctic Ocean data. The data are pooled into five year intervals because of overlapping ship cruises. Whaling effort is reported as whales taken per ship per five year interval. These data, extracted from Townsend (1935), represent an unknown fraction of the total number of bowhead whales taken for all years from the Atlantic Ocean and Pacific Ocean populations.

Depending upon ice conditions, the first belugas are reported to appear off Pt. Hope in late April (Fiscus and Marquette, 1975) although sightings exist in the northern Bering and southern Chukchi Seas during February and March (Kleinenberg et al., 1964; authors, pers. obs.). Belugas are believed to move north as late as July, as evidenced by hunting records at Pt. Hope (Foote and Williamson, 1966). By May and June, some belugas reach the eastern Beaufort Sea near Banks Island (Sergeant and Hoek, 1974), and the eastern Siberian coast (Klinkhart, 1966). It is unclear what portion of the population arriving at Banks Island comes from Alaskan waters. Fraker (pers. comm.) feels that many belugas winter in eastern Canada.

During the summer and fall belugas enter river estuaries as soon as the ice moves offshore (Klinkhart, 1966; Fraker, 1977). On 24 June, 50 belugas were observed at the mouth of the Pitmegea River just northeast of Cape Lisburne (Childs, 1969, in AEIDC). In Kotzebue Sound during the fall, belugas have been reported near Sheshalik, across Hotham Inlet north of Kotzebue (Foote and Williamson, 1966). The species is believed to breed and calve in southeastern Kotzebue Sound (U. S. Department of the Interior, 1974, in AEIDC).

For those animals wintering in Alaska, the fall migration west from the Mackenzie River delta commences in September (Sergeant and Hoek, 1974); however, the precise route and direction of travel is unclear. Movement probably precedes the fall freeze-over (LeResche and Hinman, 1973) since belugas are not able to maintain breathing holes in thick ice, and are probably not capable of swimming long distances underwater (Fraker, 1977).

Klinkhart (1966) records a seasonal shift in feeding habits of belugas. While offshore in the Arctic Ocean these animals presumably feed on a variety of fish, especially arctic cod, crustaceans and squid (Sergeant and Hoek, 1974).

Study Area

The study area includes the Bering Sea north from St. Lawrence Island and east of the US-USSR 1867 Convention line, north into the Chukchi Sea to approximately 72° N. Latitude, and east into the Beaufort Sea to the US-Canadian border at 141° W. Longitude.

Aerial surveys in the Beaufort Sea took place within 50 km of shore, because we thought that open water leads did not normally occur far from land. In the Chukchi Sea, however, surveys were flown offshore to delineate leads. The most heavily surveyed area of the Arctic Ocean was between 69° N. Latitude and 72° N. Latitude to within a few kilometers of shore.

The whale counting camps were located on shore-fast ice: one approximately eight miles northwest of Pt. Barrow and the other eight miles west of the village of Barrow (Figure 2).

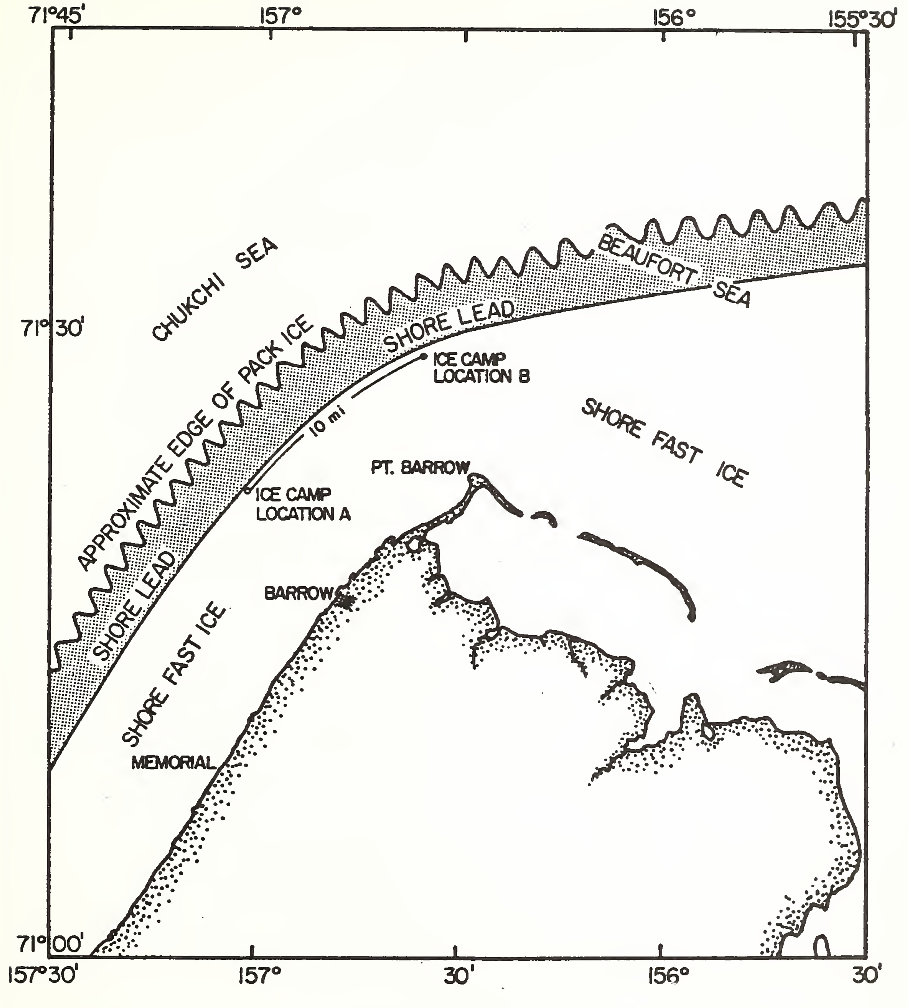

Figure 2. Study area map of bowhead and beluga whale census camps on the shore-fast ice northwest (Location A) and north (Location B) of Barrow, Alaska. The location of the shore lead in the Beaufort Sea is approximate, occurring closer to shore as the distance from Pt. Barrow increases to the east.

Materials and Methods

Aerial survey

Aerial surveys over the pack ice and open leads were conducted at elevations of 200 to 1,000 feet depending upon cloud conditions. The aircraft used was a twin engine Grumman Otter, chartered from the Naval Arctic Research Laboratory. An On-Track II navigational system, available in the Otter, provided a means of locating our position to within 1 nmi^2. This equipment allowed us to determine precisely the position of each sighting. Also, the On-Track II was used to determine the position of the ice camps in relation to the shore, for later plotting on charts.

Two to three observers were used, each acting as his own recorder, noting the details of each sighting, including environmental conditions. The pilot proved to be a valuable spotter. Communications between observers were poor, but will be improved in 1977 with the addition of an intercom system (see Braham et al., 1977). One observer sat in the co-pilot's seat and acted as the "chief spotter" and photographer. A single lens reflex 35 mm F2S Nikon camera was used to take the photographs, with 105 and 135 mm lenses and high speed Ektachrome film (ASA 160). [Reference to trade names does not imply endorsement by NMFS, NOAA.]

Ice camp

Counts of bowhead and beluga whales were made by observers standing on the ice next to the near-shore lead. As the whales moved past the observers, the following information was scored: number of animals, direction of travel, general behavior, approximate size of each animal, weather conditions, time of day and, when possible, length of time animal(s) spent at the surface and duration of dive. One and sometimes two observers stood watch for four to six hours rotating on a 24 hour basis between 25 April and 2 June 1976.

Two camps were used during the season (Figure 2), but were simultaneously occupied only once (13 May). One camp was used when ice conditions near the other were unsafe. The southern ice camp (Location A) was used primarily early in the season (April-May) and the north camp (Location B) later (May-June) (Figure 2). The camps were located 1/4 to 1/2 mile shoreward from the lead, which placed the observer(s) some distance from the base camp.

Working in concert, the ice camp and aerial survey teams maximized our chances of providing the geographic coverage necessary to delineate bowhead and beluga movements.

Laboratory

A system was developed for logging, checking, editing and final processing of the sighting data. A description of the procedures and a flow diagram of the four-phase program are included in Fiscus and Braham (1976).

Results and Discussion

Aerial survey and ice camp sighting data for the spring 1976 field season are summarized chronologically in Table 1. Observations totalling 422 hours were made from the ice camp during 30 survey days (average 14 hours/day) and approximately 93 hours were spent flying during 19 survey days (average 5 hours/day). The aerial survey tracklines are summarized in Figure 3.

Bowhead whale

Spring 1976 counts. There were 357 bowhead whales observed migrating by the ice camp from 25 April to 2 June 1976. Some 259 whales were seen by the ice camp census crew (73%), and 98 were seen by Eskimo hunters stationed by our camp (Table 1). Eskimo sightings were independent from ours, but were included in the total count if the following criteria were met:

1. The Eskimos reported a whale passing our camp unseen by us.
2. The Eskimos were seen pursuing a whale up or down the lead from our camp, and we were sure that the animal had not been seen by us.
3. A shot was fired at a whale we had not seen.
4. Some of the Eskimos became excited over the observation of a whale made by other Eskimos, and we were sure that the animal had not been seen by us.

As the season progressed, and our census crew became more experienced, the proportion of whales seen by our crew to that seen by the Eskimos increased (Figure 4).

The mean number of bowheads seen per hour by observers stationed in the ice camp was 0.61 (standard deviation = 2.73), n=30, or 0.85 (SD = 3.04), n=30 if the Eskimo sightings are included in the total. From these two values an estimate of 571-796 bowhead whales passed our ice camp in the nearshore lead between 25 April and 2 June 1976. This estimate applies only to the time interval of 25 April to 2 June (i.e., 936 hours X 0.61 = 571; 936 hours X 0.85 = 796), and should be thought of only as an index to the number of bowheads that passed the ice camp. Whales were observed moving by Barrow prior to the initiation of our ice study, and whales were still moving by at least until 20 June when the last aerial survey was conducted.

The accuracy of the estimate certainly is affected by that proportion of whales which moved by the ice camp but were not detected. The probability of detecting whales which moved by within 2 miles of the camp is quite high, a probability which is based on intuitive feelings of ice camp observers. Animals passing farther offshore probably go undetected. Concurrent aerial surveys flown offshore, west of Barrow, did not reveal any use of offshore leads by bowheads (Figure 5). East of Point Barrow, bowheads were seen in leads farther offshore (Figure 5).

Table 1. Number of bowhead and beluga whales sighted by the ice station counting crew, by Eskimos, and by the aerial survey team. See text for an explanation of the Eskimos' role in the counts. Dashed spaces indicate no surveys took place.

	Number of Bowheads			Number of Beluga	
Date	Ice Crew	Eskimos	Aerial Crew	Ice Crew	Aerial Crew
25 April	3	2	-	0	-
29 "	11	6	4	0	248
30 "	7	10	-	0	-
1 May	17	3	6	0	48
2 "	3	6	-	0	-
3 "	1	1	3	0	67
5 "	11	9	-	0	-
6 "	16	19	-	0	-
7 "	8	1	-	0	-
8 "	4	1	34	0	85
9 "	2	0	5	0	27
10 "	0	1	-	0	-
11 "	0	0	-	0	-
12 "	0	0	2	0	0
13 "	21	7	-	0	-
14 "	5	0	-	0	-
15 "	11	3	18	0	134
16 "	18	11	-	2	-
17 "	26	9	-	0	-
18 "	52	9	-	100	-
19 "	1	0	3	0	8
20 "	-	-	0	-	20
21 "	4	0	-	0	-
22 "	19	0	4	207	129
23 "	0	0	-	0	-
24 "	9	0	3	0	1
25 "	1	0	-	0	-
26 "	6	0	-	0	-
28 "	-	-	1	-	0
31 "	1	-	4	0	1
1 June	1	-	3	0	144
2 "	1	-	-	0	-
4 "	-	-	15	-	35
5 "	-	-	2	-	0
18 "	-	-	0	-	12
19 "	-	-	1	-	61
20 "	-	-	0	-	0
Totals	259	98	108	309	1,020

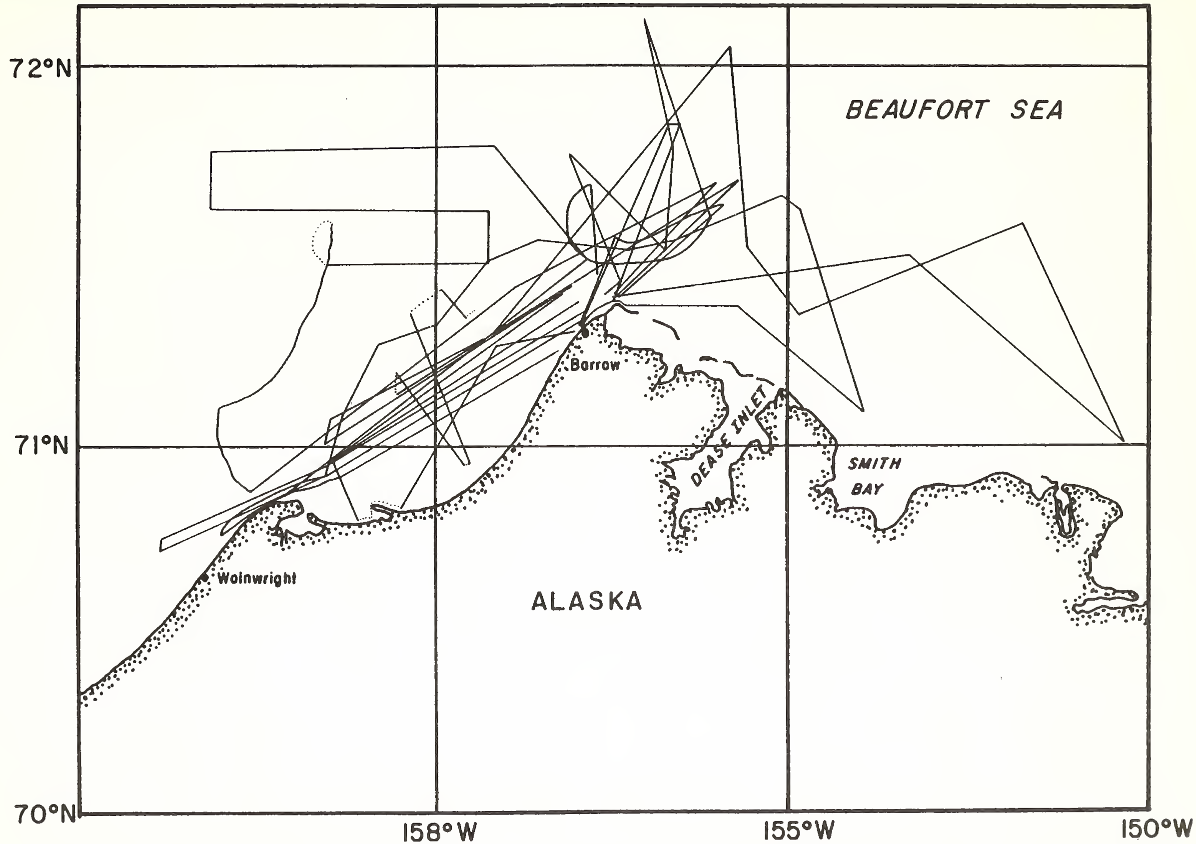

Figure 3. Aerial survey tracklines during spring 1976 bowhead and beluga whale research, conducted from the Naval Arctic Research Laboratory, Barrow, Alaska.

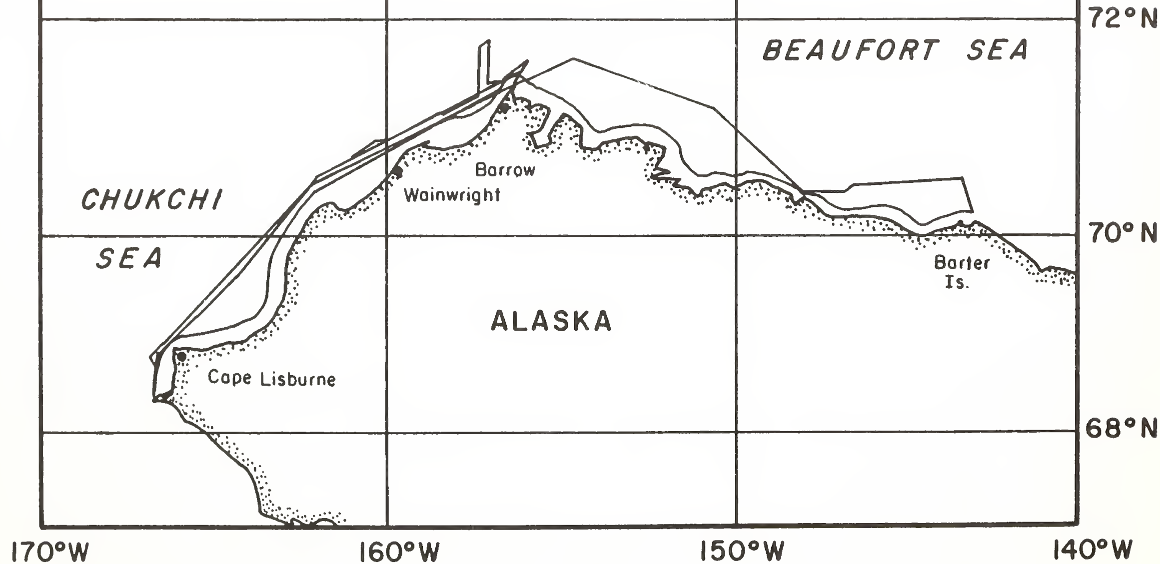

Figure 3, continued.

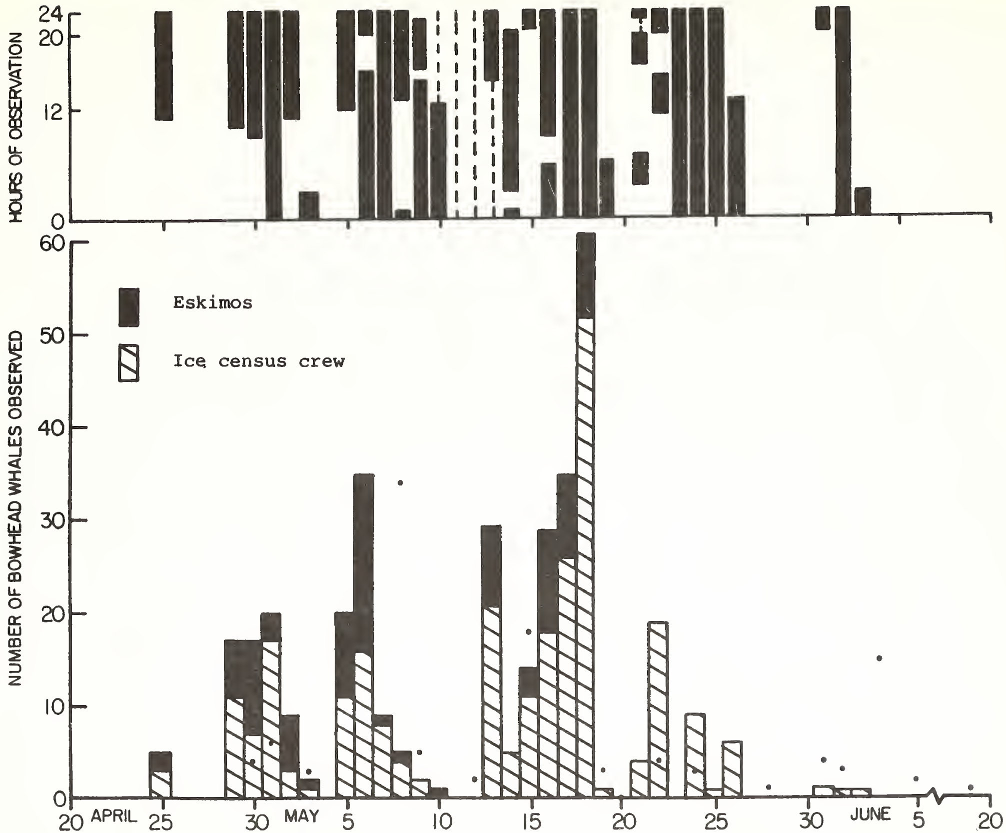

Figure 4. Histogram of the numbers of bowhead whales observed along the shore-fast ice lead at Barrow, Alaska, 1976. Sightings are related to the hours in the day when the census crew was observing. Dots (·) indicate the number of bowheads seen by the aerial survey team on that date. Dashed lines indicate an intermittent watch effort.

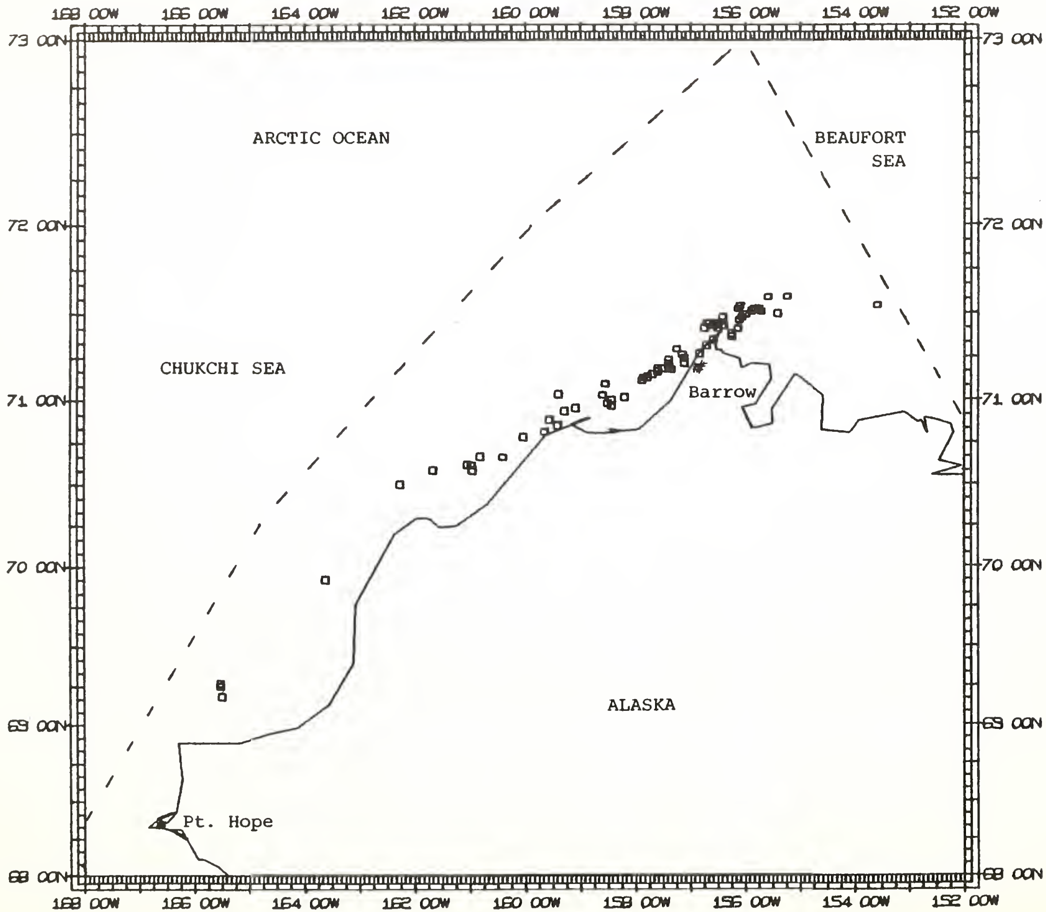

Figure 5. Spring 1976 aerial survey sightings of bowhead whales, Balaena mysticetus, along the northwest coast of Alaska. Dashed line represents the maximum extent of offshore aerial surveys.

Movement of bowheads through a lead system may be related to the opening and closing of the lead. Results based on ice camp counts suggest that animals may somehow "bunch up" when a lead closes, and resume migration when the lead reopens. Small peaks in the number of whales moving by Barrow occurred on 30 April and 1, 6, 13 and 22 May (Figure 4). Following each peak, there was a gradual drop off in the number of bowheads passing the ice camp. Preceding each peak, the lead was essentially closed for one or more days. This pattern is precisely the one to expect if migrating animals were being stalled by the closing of the lead.

The rapid build-up and peak in numbers on 18 May conceivably was the result of a large scale closing of the lead southwest of Pt. Barrow. With the re-opening of the lead, bowheads could resume their migration. Through the telescoping effect of animals moving from areas of higher to lower density (newly opened lead), the major pulse of the animals moving by any one observation point would appear as a rapid increase and peak. The appearance of this pulse would be exactly opposite of the pulse created by local closures of leads.

Much of the above discussion is conjecture, but we do have direct evidence that whales group at the end of leads which have closed. Large groups of animals were observed during aerial surveys (e.g., 8 and 15 May, Figure 4) in a lead which was closed northeast of Pt. Barrow.

Some of the fluctuations in the data (Figure 4) are undoubtedly the result of temporal migratory patterns. The large number of animals observed 12-18 May can also be explained as a peak in migration. Temporal movements on a diurnal scale were investigated by comparing the hourly rate of animals seen in the A.M. (0001-1200) versus the P.M. (1201-2400). No difference was found, which suggests that there is no diurnal periodicity. This point needs further study.

The number of animals seen per hour throughout the entire period shows that the maximum rates occurred on 15, 18 and 22 May, shortly after the lead had reopened. The number per hour seen later in the season (23 May - 2 June) was about half (0.23 animals/hour) of that seen earlier (29 April - 8 May) when the average number seen was 0.50 per hour. From 13 to 22 May, the lead opened and closed four times, resulting in four associated sighting peaks.

Distribution. Aerial survey and ice station sightings show that the majority (54%) of the bowheads migrating past Barrow in 1976 did so during the middle third of the survey period (9-18 May). This result may be significant because, if the bowhead migration pattern displays a narrow temporal peak throughout the animal's range (i.e., from the Bering Sea to the Beaufort Sea), then a large segment of the population could be vulnerable to oil development activities within a short period of time.

Fewer aerial survey sightings were made near the shore of the western Beaufort Sea than along the coast of the eastern Chukchi Sea (Figure 5). (Note: Point Barrow is considered the dividing line of the two Seas.) Although weather restricted surveys along the northern coast (Beaufort Sea), more of our offshore sightings were northeast of Point Barrow than west of Barrow. This difference suggests that the easterly migration past Pt. Barrow is farther offshore.

There were very few spring 1976 bowhead whale sightings reported to us from outside the Barrow study area. Eleven (11) sightings from the southern Chukchi and Bering Seas were submitted (Table 2). Several independent observers reported seeing up to four bowhead whales in the western Bristol Bay-St. George Basin areas in April (Table 2). Whaling records in Townsend (1935) suggest that few bowheads were taken in the southeastern Bering Sea. The 1976 sightings thus confirm the probable southeastward extent of the bowhead range. The remaining sightings were essentially in the western Bering Sea within the suggested migration route of the species (Table 2). The two animals seen in the Chukchi Sea on 12 June (Table 2) were not actively moving north. Townsend's (1935) plots of bowheads in the southern Chukchi Sea from June to August suggest that a protracted migration occurs. Many animals were taken during the summer north and south of the Bering Strait (Townsend, 1935) suggesting that animals were still migrating north as late as July or August. The peak migration period of the bowhead, then, appears to be from March through July.

Fall sightings. Bowhead sighting data during the fall are minimal. Clifford Fiscus sighted bowheads near Cape Simpson between 12 and 22 September 1974. The highest number he saw was 57 on 18 September 1974. Only two bowheads were seen during the fall 1975 surveys, because of poor ice and weather conditions. Between 16 and 26 September 1976, Robert Everitt sighted over 100 bowhead whales in the same general area as those seen in 1974 (southeast of Pt. Barrow). The greatest number seen during a single day was 47 on 21 September 1976. These sightings suggest that the area from Smith Bay to Pt. Barrow represents a very important congregation site for bowheads prior to their southward migration. This apparent "critical habitat" is presented in Figure 6.

Sighting records from other OCSEAP contractees have been sent to us. In August 1975, Dr. Carleton Ray (pers. comm., RU 34) sighted 74 bowheads northeast of Icy Cape (about 70°30' N. Latitude, 161°00' W. Longitude). He also observed large concentrations of bowheads between Smith Bay and Pt. Barrow and, in October 1975, saw six bowheads in the Chukchi Sea at about 70°30' N. Latitude, 163°-169°30' W. Longitude. Data collected by Ray in 1975 would suggest that because of heavy ice in that year, bowheads began their southward migration earlier than in 1974 and 1976.

Although the data are sparse, they suggest that bowheads move west and south from Pt. Barrow during the fall, probably in September. We have, as does Ray (pers. comm.), sightings that place bowheads at three locations during September: 1) east along the northern coast of Alaska within 100 km of Pt. Barrow; 2) south of Barrow along the coast to Peard Bay; and 3) west some 100 km into the Chukchi Sea.

Berzin (pers. comm.) reports seeing bowhead whales on the Soviet side of the US-USSR 1867 Convention line, 8-11 October 1974 and 1975 (Table 3). Cook (1926) describes taking bowheads near Herald Island (USSR); and Townsend's (1935) plots indicate that the summer-fall range of the species extended to Wrangell Island (USSR).

Table 2. Summary of the number of bowhead and beluga whale sightings in the Bering and southern Chukchi Seas by date from aerial (A) or vessel (V) surveys during 1976. The general location of each sighting and the individual or survey group reporting the data are included. RU 67 or 69 denotes the OCSEAP research team conducting the survey.

Date	Species	Number of Animals	General Location	Survey Type	Survey Observer
15 March	Beluga	8	N. Bering Sea	A	RU 69
18 "	Beluga	18	N. Bering Sea	A	RU 69
19 "	Beluga	2	N. Bering Sea	A	RU 69
9 April	Beluga	33	E. Bristol Bay	A	RU 67
9 "	Bowhead	1	W. Bristol Bay	A	J. Hall[1]
14 "	Bowhead	1	W. Bering Sea	A	G. Fedoseev[1]
15 "	Bowhead	1	S.W. St. Matthew Is.	A	G. Fedoseev
18 "	Bowhead	1	W. St. Lawrence Is.	A	G. Fedoseev
19 "	Bowhead[2]	2	W. Pribilof Is.	V	P. McGuire[1]
19 "	Bowhead	1	E. St. Lawrence Is.	A	RU 67
19 "	Beluga	4	E. St. Lawrence Is.	A	RU 67
19 "	Beluga	79	N.W. St. Lawrence Is.	A	C. Ray[1]
20 "	Bowhead[2]	2	W. Pribilof Is.	V	P. McGuire
20 "	Bowhead	1	N.W. St. Lawrence Is.	A	RU 69
20 "	Beluga	4	N. Bering Sea	A	RU 69
21 "	Bowhead[2]	2	W. Pribilof Is.	V	P. McGuire
21 "	Bowhead	2	S. Bering Strait	A	RU 69
21 "	Beluga	118	S. Chukchi Sea, N. St. Lawrence Is.	A	RU 69
22 "	Beluga	25	N.W. St. Lawrence Is.	A	RU 69
23 "	Bowhead	1	W. Bristol Bay	A	J. Burns[1]
23 "	Beluga	1	N.E. Norton Sound	A	RU 69
6 May	Beluga	10	W. Bering Sea	A	G. Fedoseev
7 "	Beluga	2	W. Bering Sea	A	G. Fedoseev
12 June	Bowhead	2	S. Chukchi Sea	A	RU 69
13 "	Beluga	18	S.W. Norton Sound	A	RU 67
26 August	Beluga	4	W. Norton Sound	A	RU 67

[1] John Burns, Alaska Dept. of Fish and Game, Fairbanks, AK
Genadi Fedoseev, TINRO, Magadan, USSR
John Hall, U. S. Fish and Wildlife Service, Anchorage, AK
Patrick McGuire, Marine Mammal Division, Seattle, WA
Carleton Ray, Johns Hopkins University, Baltimore, MD

[2] Probably the same animals.

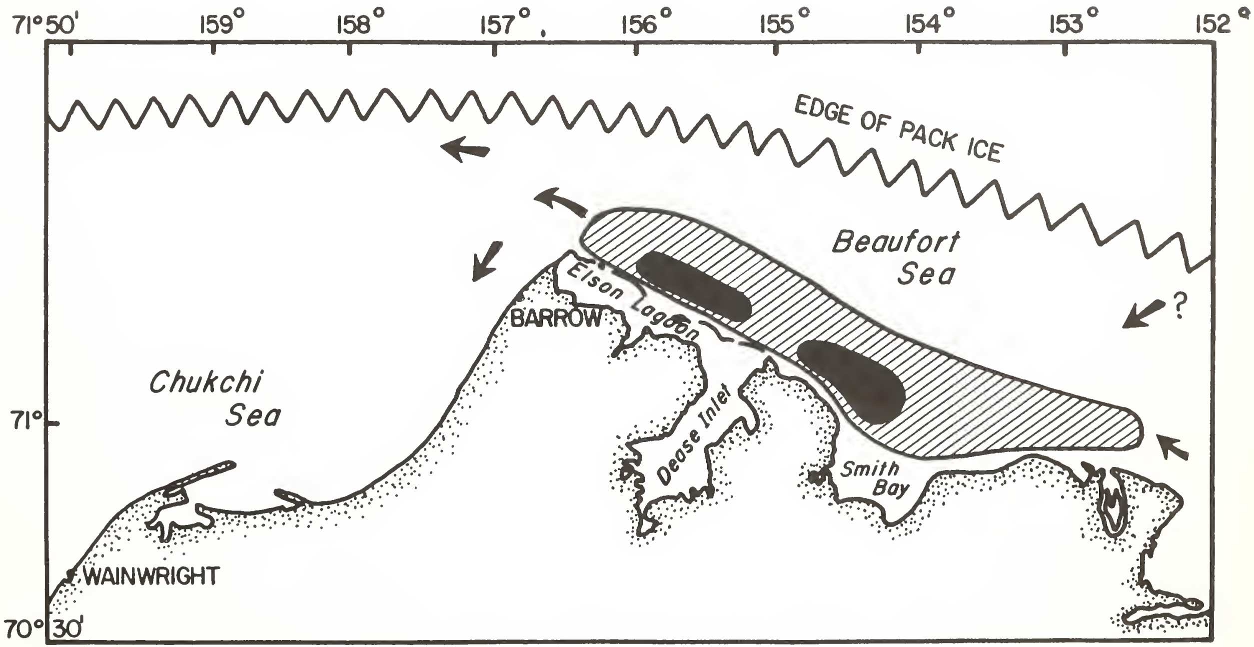

Figure 6. Area map of the northwest coast of Alaska depicting the region where bowhead whales concentrate during the fall. Darkened areas are areas of highest density; hatched areas, where animals are less dense. Movement into and out of this region remains unclear.

Table 3. Sightings of bowhead whales in the southern Chukchi and northern Bering Seas west of the US-USSR 1867 Convention line in the fall of 1974 and 1975. Data supplied by Dr. A. A. Berzin, TINRO, Valdivostok, U.S.S.R.

General Location	Number of bowheads
NW of St. Lawrence Island	3
SW Bering Strait	5
Bering Strait	2
NW of Bering Strait	4
NW of Shishmaref (US sector)	3
NE of Chukotski Peninsula (approximate)	
Cape Serdzekamen	1
Cape Chautau	20
Kolyuchin Island	60
Cape Vankarem	60
Cape Syeverni	23

Many bowheads apparently migrate to the northern coast of Siberia in the fall before moving south through the Bering Strait. Since few animals are reported to occur along the Siberian coast during the spring (G. Fedoseev, V. Golt'sev and A. Berzin, pers. comm.), the majority of animals appear to move north into the eastern Chukchi Sea in the spring and during the fall south into the western Chukchi Sea. Additional fall sighting data from the Chukchi Sea is needed.

Beluga whales

Spring 1976 counts. Aerial survey and ice station data on beluga whales along the northwest coast of Alaska during the spring of 1976 are summarized in Table 1 and Figure 7. The mean number of belugas seen per day for 19 aerial survey days from 29 April to 20 June 1976 was 54 (SEM = 12.4), n=19. Assuming an equal chance that belugas would be encountered on any of the 33 days not surveyed, a minimum estimate of 2,800 animals migrated past the northwestern coast during the survey period. This value was determined from 33 days not surveyed X 54 animals/day + 1,020 actually seen = 2,802. The 93 flying hours (some of which were not spent over the lead) during the 19 survey days represented only 20% of the total hours accruing between 29 April and 20 June.

Any determination of the total number of belugas which may have migrated past Barrow, based on 1976 aerial survey data, is biased because:

1. Duplicate sightings occurred on the same day.

2. We do not know if belugas migrate with any periodicity.

3. A detailed analysis of offshore sighting data has not been completed. Preliminary findings indicate that belugas use offshore leads.

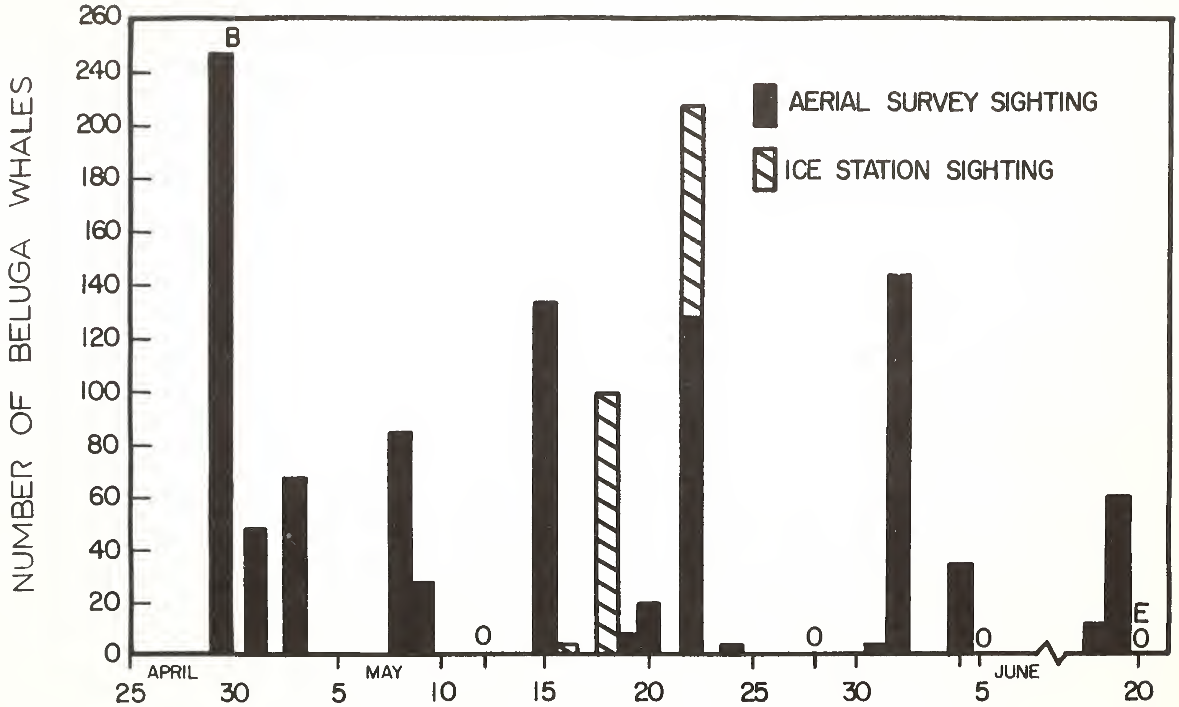

Figure 7. Numbers of beluga whales observed during aerial and ice-based surveys along the shore-fast ice lead between Barrow and Wainwright, Alaska, during spring 1976. B and E denote the dates of first and last aerial surveys. O's denote aerial surveys during which no belugas were observed.

4. The variability between sample days, which indicates clumped migratory patterns, makes extrapolation to other times of a survey day difficult.

5. Animals under the water or ice are overlooked. Also, belugas appeared to avoid our approaching aircraft. McVay (1973) reported similar behavior.

Caution should thus be exercised in using any value as an estimate of the total number passing by the vicinity of Barrow during the sample period.

Distribution. No pattern of numeric distribution with respect to time occurred in the data (Table 1). As many belugas were seen during the last part of the season as during the first part. The fact that 24% (248) of the total scored (1,020) was seen on the first survey day helps to confirm our feeling that belugas may migrate somewhat earlier than bowheads.

Our data also suggest that belugas use offshore leads with greater frequency than do bowheads (Figures 5 and 8). Additional offhsore surveys during 1977 should help to confirm this possibility.

Sightings of beluga whales in the Bering Sea and southern Chukchi Sea during the spring are reported in Table 2. Most observations occurred in the northern Bering Sea; however, more surveys were conducted there. Carleton Ray (pers. comm., RU 34) reports seeing over 300 beluga whales northwest of Port Moller in Bristol Bay on 13 April 1976. We do not know whether this group, and perhaps the group observed by us in a small polynya on 9 April (Table 2) are part of the "resident" population in Bristol Bay. Ray (pers. comm.) reports that approximately 47 beluga whales were observed northwest of St. Matthew Island in April 1975. We also do not know whether this group is strictly local or contains animals that migrated north past St. Lawrence Island.

Fall sightings. Few sightings of belugas have been made during our 1975 and 1976 aerial surveys of the Chukchi and Beaufort Seas. Sightings by other researchers have been more frequent. In September 1974, Ray (pers. comm., RU 34) sighted 23 belugas in the western Beaufort Sea northeast of Pt. Barrow. His most significant observation occurred in the pack ice in the area of 73°00' N. Latitude, 162°00' W. Longitude, where "a thousand or more" belugas were seen over the continental slope. In October 1975, Ray reported seeing 175-180 beluga in the southern Chukchi Sea just east of the US-USSR 1867 Convention line. Data collected in the fall suggest that belugas are spread throughout the Chukchi Sea.

Belugas are known to occur in rivers and estuaries in Bristol Bay, Norton Sound (Yukon River delta), Kotzebue Sound, and along the northwestern coast of Alaska. We need to determine whether these groups represent local populations or whether intermixing occurs in the Bering Sea during the winter months.

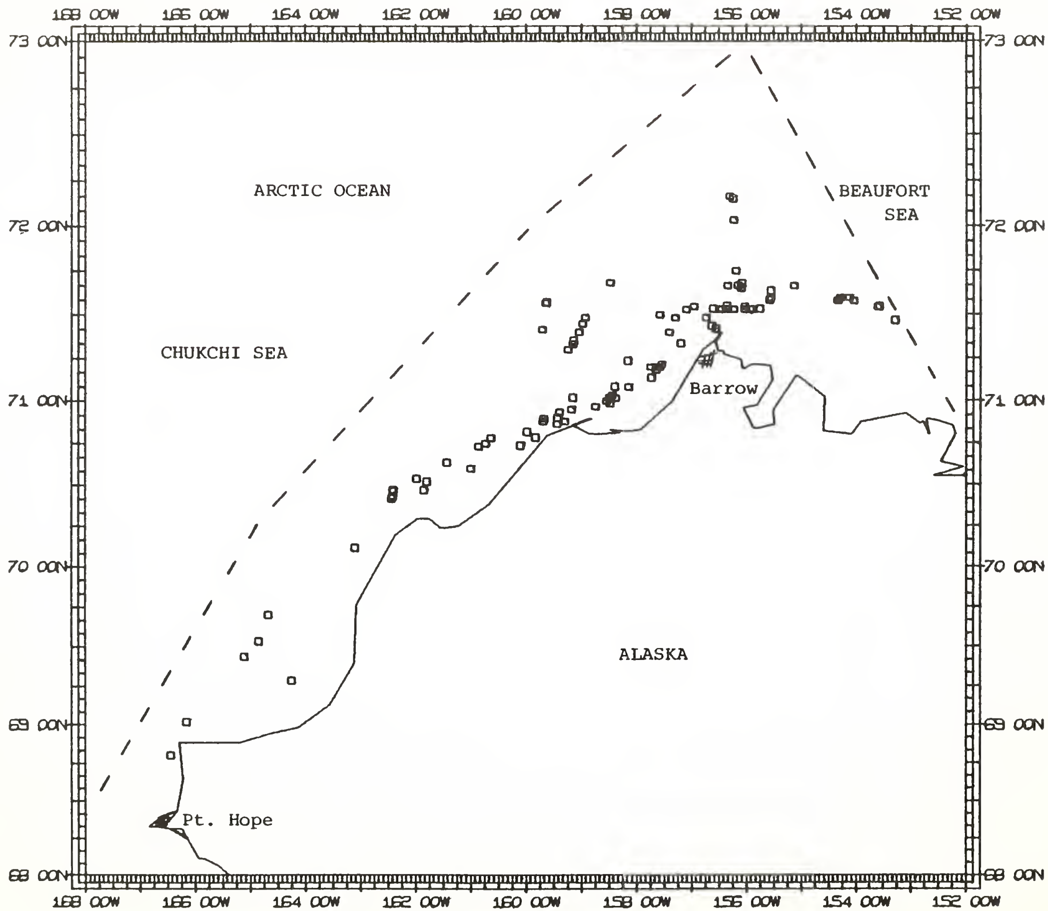

Figure 8. Spring 1976 aerial survey sightings of beluga whales, Delphinapterus leucus, along the northwest coast of Alaska. Dashed line represents the maximum extent of offshore surveys.

Comparison of survey methods

More beluga whales were seen during aerial surveys (total = 1,020) for the time spent sampling (about 93 hours) than were observed by the ice camp crew (total = 309 during 422 hours) (x^2: P<0.001). For this reason, aerial surveys were considered more efficient (numbers of animals per unit of time) for observing beluga whales. The same result occurred for bowheads. That is, more bowheads were seen during a unit of time in the air than on the ice (x^2:P<0.01). However, flight time is more costly, and it is more difficult to design a statistically reliable sampling technique for aerial surveys than for ice camp work. Additional analyses of the data are needed, however, because duplicate sightings undoubtedly occurred during aerial surveys, thus confounding any interpretation.

An additional test was performed to determine if there was any difference between the number of bowheads seen versus belugas when comparing aerial survey and ice camp counting methods. More bowheads than belugas were seen from the ice than expected (x^2:P<0.001). It would appear, then, that more reliable index of abundance data will be forthcoming for bowheads from ice camp sightings, and for belugas from aerial survey sightings.

Conclusions and Recommendations

The question of bowhead population abundance remains unanswered. From data collected in 1976 a total estimate cannot be made. Given a minimum population level of "...only a few thousand at most..." (Rice, 1974:193), fewer bowheads have been seen in the eastern Beaufort Sea (e.g., Banks Island-Mackenzie River delta area) than would be expected if most animals migrate east past Pt. Barrow in the spring. Since they have traditionally been hunted in the northern and western Chukchi Sea during the summer (Cook, 1926; Townsend, 1935; and others), it seems reasonable to predict that some bowheads remain in the Chukchi Sea or migrate to that area later in the spring (i.e., June-July). Future projections of abundance may have to take into account either a delayed or truncated migration.

Although a limited amount of data exists from one year of field work, evidence indicates that the bowhead whales which do migrate into the Beaufort Sea in the spring do so offshore rather than along the coast (Figure 9). We feel that at least some bowheads (perhaps most) migrate north through the pack ice to Banks Island, Canada, and then move south to the western Canadian coast in the summer. This hypothesis is based on five clues: 1) NOAA satellite photographs for 1974, 1976 and 1977 indicate that leads form offshore in a direct line from Pt. Barrow to Banks Island (Marko, 1975), whereas the lead(s) running east and west along the north coast of Alaska are less persistent; 2) bowheads appear to arrive at Banks Island earlier in the year (May) than at the Mackenzie River delta (Sergeant and Hoek, 1974; Fraker, 1977); 3) no sightings have been made in the spring and early summer for the nearshore leads along the northern coast of Alaska (although bad weather has prevented extensive aerial surveys); 4) Eskimo whaling occurs along the northeastern coast of Alaska in the fall, but not in the spring; and 5) commercial whalers overwintering at Herschel

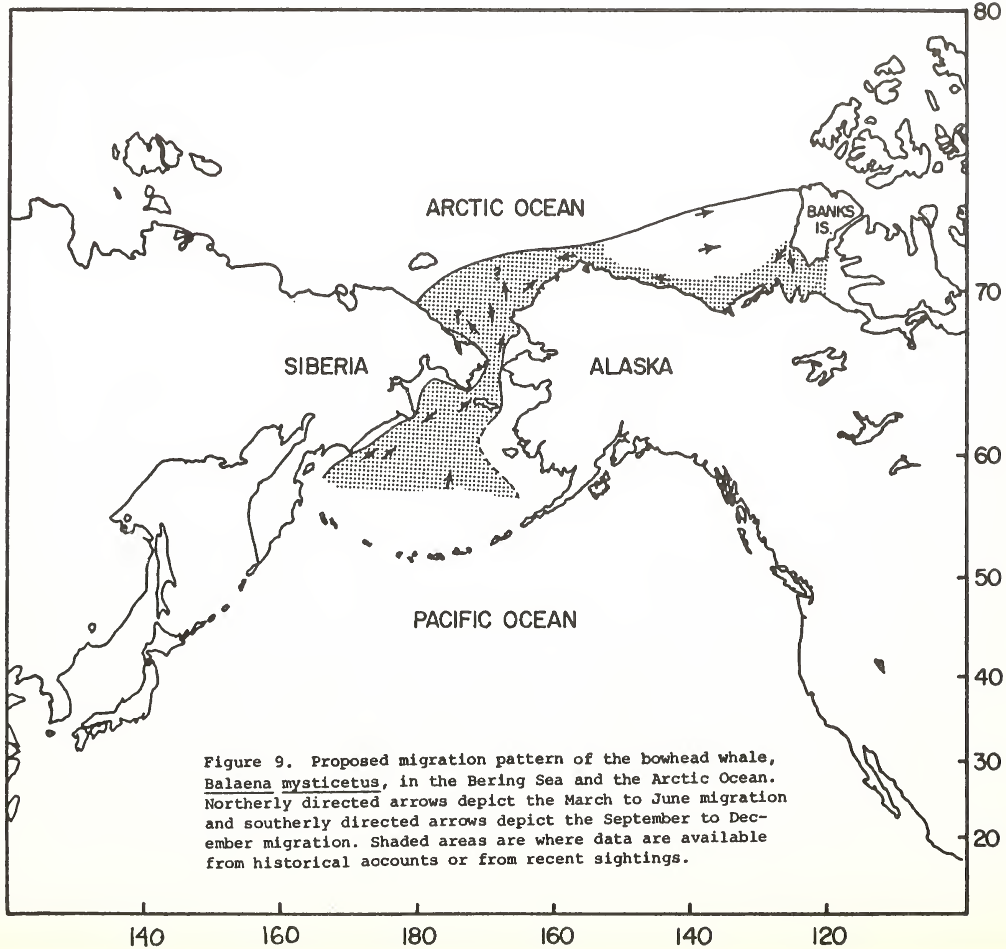

Figure 9. Proposed migration pattern of the bowhead whale, Balaena mysticetus, in the Bering Sea and the Arctic Ocean. Northerly directed arrows depict the March to June migration and southerly directed arrows depict the September to December migration. Shaded areas are where data are available from historical aocounts or from recent sightings.

Island, Canada, in the late 1800's reported finding very few bowheads in open water in the early summer along the northeastern coast of Alaska. Rather, the animals were found near the southwestern coast of Banks Island (Cook, 1926). This hypothesis should be tested because, if true, bowheads would be more vulnerable to Beaufort Sea oil and gas development activities in the fall than in the spring.

The fall migration of bowheads that spend summer in the eastern Beaufort Sea is along the Alaska coast westward to Point Barrow and then into the Chukchi Sea (Figure 8). The waters off Cape Simpson and Smith Bay (71°-71°20' N. Latitude, 154°-156° W. Longitude) have been identified as a potential "critical habitat" for the bowhead (Figure 6).

On 8 May 1976, copulatory behavior was photographed northeast of Pt. Barrow (Figure 10). To our knowledge, this observation is the first physical evidence of this type of reproductive activity in bowheads. A more detailed account of this occurrence is in preparation. On the same day, an apparent female and young of the year calf (less than half the size of the cow) were photographed (Figure 11). Although we are not certain that the northern Bering-southern Chukchi Seas and Beaufort Sea areas are the breeding grounds for the bowhead, copulation and parturition within the species occur during the northern migration and in or adjacent to the oil lease sites (i.e., Norton, Hope and Beaufort basins).

Evidence indicates that some beluga whales migrate farther offshore than do bowhead whales in the Chukchi and Beaufort Seas, and that belugas may not be as restricted from moving into the pack ice as first thought. Also, numerous convex impressions made by belugas in thin ice were observed (also see McVay, 1973), indicating that (directional) movement may occur under thin or in fractured ice.

General surveys for beluga whales should shift to localized studies after the FY 77 field season. It would seem to be more cost productive to study this species at specific locales within the oil lease areas (e.g., in Kotzebue Sound June-August, during the breeding season; or in Norton Sound and Bristol Bay in the summer). Development of a tagging or radio tracking program should provide a means of better identifying local and regional beluga movements, and of identifying breeding and calving areas as well as periods of feeding.

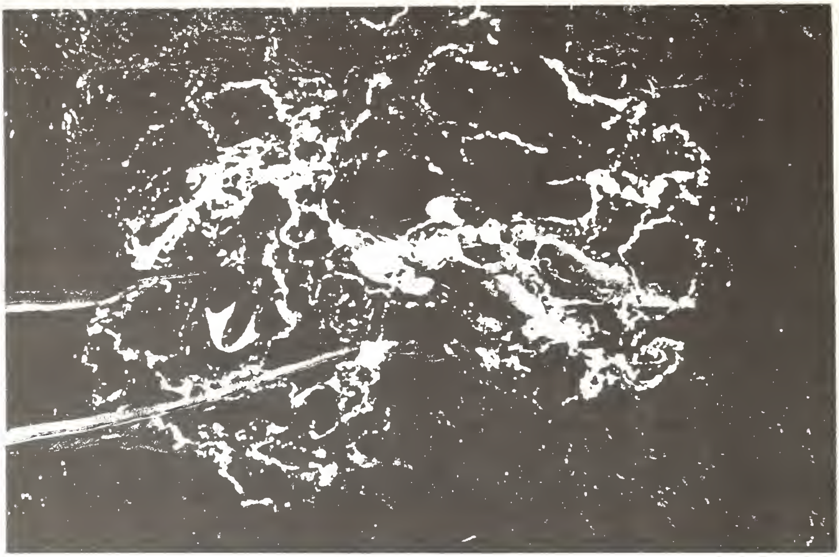

Figure 10. Seven bowhead whales engaged in copulatory activities. Photographed by B. Krogman, 8 May 1976, northeast of Pt. Barrow, Alaska.

Figure 11. Apparent female bowhead whale with young of the year calf. Photographed bv B. Krogman, 8 May 1976, northeast of Pt. Barrow, Alaska.

Acknowledgements

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Pilots and staff members of the Naval Arctic Research Laboratory, Barrow, Alaska, cooperated with us by providing logistics support. Especially helpful was Richard Heyme, who provided us with a hydrophone for use in determining presence of certain marine mammals near our ice camp.

Any success we had on the ice during the 1976 spring season was due in part to the hospitality extended to us by Eskimos from Barrow. We very much appreciated their assistance, particularly in the identification of unsafe ice conditions.

We also thank John Burns, Dr. Genadi Fedoseev, John Hall and Dr. Carleton Ray for providing unpublished sightings of bowhead and beluga whales.

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